Spring 5-31-1972

The creep and stress relaxation behavior of silver bearing copper wire

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THE CREEP AND STRESS RELAXATION BEHAVIOR OF SILVER BEARING COPPER WIRE

A THESIS

PRESENTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE
OF
MASTER OF SCIENCE IN MECHANICAL ENGINEERING
AT
NEWARK COLLEGE OF ENGINEERING

Newark, New Jersey
1972

APPROVAL OF THESIS

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by

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for

DEPARTMENT OF MECHANICAL ENGINEERING
NEWARK COLLEGE OF ENGINEERING

by

FACULTY COMMITTEE

APPROVED:

NEWARK, NEW JERSEY
JUNE, 1972

ABSTRACT

Creep and stress-relaxation experiments were performed on silverless and silver bearing copper in the temperature range 73F to 250F. The creep experiments were conducted at constant load and temperature, the stress-relaxation tests at constant total strain and temperature for a total time period of 1000 hours. The effect of silver addition of up to 0.2 percent w/o (60oz per ton) on the creep and stress-relaxation behavior of spectrographically pure copper (99.999+ Cu) as well as on that of tough pitch and oxygen free coppers of lesser purity was studied. Spectrographically pure copper was found to be much more susceptible to creep deformation than commercial copper containing small amounts of impurities. The high purity copper appears to fail by separation of the grain boundaries with incipient microcrack formation. These microcracks act as stress concentrations, thus accelerating the creep rate. Oxide particles, present in tough pitch copper, act as stress raisers and cause this material to have a lower resistance to creep and stress relaxation than

oxygen free copper containing about the same level of other impurities (with the exception of oxygen). The addition of silver to either of these two conductor materials raises the recrystallization temperature and therefore results in material having a much finer and more uniform grain structure. This results in improved resistance to creep and stress relaxation and inhibits the formation of microcracks by grain boundary separation. Creep and stress-relaxation data are presented at two stress levels and three temperatures for each of the materials studied, that will permit designers to formulate appropriate time, temperature, stress-strain relations.

Silver addition in excess of 25oz per ton (0.09 w/o%) produces further improvement in resistance to creep and stress relaxation. Sufficient strengthening is achieved, however, with the 25oz per ton addition in the temperature range of interest (73F to 250F) to justify the use of this material as a suitable and economical replacement for tough pitch copper in miniaturized applications where long time dimensional stability is important.

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INTRODUCTION

Many uses to which copper is put are structural in character and are subject to elevated temperature environment. One of the main uses for copper is communications wire and cable. The recent trend towards miniaturization of communication equipment with ever more stringent design parameters and tolerances requires, on the part of the equipment designer, a better understanding of the time and temperature dependence of stress and strain. Furthermore, the requirements of the newer miniaturized designs pose material problems which can no longer be met by unalloyed ETP* (electrolytic tough pitch) copper which traditionally has been used in many applications. Materials are needed which, in addition to having adequate tensile strength and ductility also possess good electrical conductivity and stress relaxation properties in the temperature range in which such equipment is being used (73F to 250F). While, as shown by Fox and Swisher[11], several copper alloy systems are available that would meet the foregoing requirements, their cost is substantially higher than that for ETP or OF (Oxygen Free) copper. Thus, while use of these alloys for selected applications seems indicated their use would not appear economically

* Designated commercially as alloy CA110.

justified for design applications having somewhat less stringent requirements, but for which ordinary ETP or OF copper is inadequate.

It has been established previously (see Review of the Literature) that the short-time, high temperature creep strength of copper containing small amounts of silver was significantly improved over that of ordinary ETP or OF copper. Such a material, if shown to have adequate design properties would have the advantages of being economically more attractive than these other alloys and of having improved conductivity (97-99% IACS)[8,11]. No information at all could be found in the literature on the stress-relaxation behavior of silver-bearing copper at any temperature. Most of the previous work on creep was done at temperatures substantially higher than those at which communications equipment is being used and, in fact close to, or above the recrystallization temperature so that the material was, in effect, changing structurally during the experiment. Extrapolation of data obtained under such conditions to temperatures below the recrystallization temperature is not justified. This Thesis is intended to provide designers with much needed information on the stress-relaxation and creep properties of silver bearing copper in the form of fine wires and in the condition of cold work in which the material retains sufficient ductility for the type of designs considered.

A typical design where such a material might find use is illustrated in Fig. 1 which shows an overcrowded main distributing frame in a telephone exchange area central office. This overcrowding has led urgency to the reduction in the physical size of the conductors being terminated on such frames. Typical jumper wires used on distributing frames are shown in Fig. 2. The reduction in the physical size of these jumper wires may be accomplished by use of thinner irradiated polyvinyl chloride insulation in combination with a reduction of the conductor diameter from 22 gage (AWG) to 24 gage (AWG). A twenty percent saving in diameter or forty percent saving in space may thus be realized.

The bulk of the interconnections made on telephone distribution frames are of the pressure type such as for example solderless-wrap or quick clip connections (Fig. 3). To insure reliable circuit performance over the 40-year design life of the connection it is essential that the contact resistance at the conductor-connector interface remain stable.

Resistance to creep, the time-dependent deformation resulting from stress and to stress relaxation, the time-dependent decrease in stress in a constrained member, play an extremely important role in insuring that the contact resistance remain stable, especially since the change in contact resistance, if it occurs, depends on interfacial movement between connector and conductor, as shown by Bond[3]. Such movement is caused by time-dependent deformation.

Review of the Literature

Tensile creep in annealed copper wire has been of considerable concern to the designers of motors and generators, because during operation, centrifugal forces set up in the rotors can cause creep in the windings. The expansion resulting therefrom, may ultimately lead to interference between moving rotor and stator. When this happens, expensive and destructive failure takes place. However, the operating temperatures of such windings are considerably higher than those of interest and most of the earlier work in this area was carried out at these higher temperatures. In 1936 Phillips and Smith[17] reported results of tensile creep studies made on hard-drawn ETP copper line wire. These wires had been drawn from 0.250 in. and 0.102 in. diameters, respectively, to a final size of 0.0285 in. diameter, producing reductions in area of 98.7 and 92.2 percent. Because of ductility requirements in the design applications of interest here and because creep depends on prior cold work, however, these data could not be applied to the problem at hand. The material of interest here should have, ideally, 6 to 10 percent elongation in 10 inches. This is produced by a reduction in area of about 11 percent ($\frac{1}{2}$ B&S No). In addition to the fact that creep varies with prior cold work, Cook and Richards[(5)] found that ETP copper strip (containing 0.044 w/o Oxygen) which had an average ready-to-finish grain size of 0.015 to 0.020 mm, and which had been cold worked to a reduction in thickness in excess of 95 percent, softened at room temperature (18C) after about 6 to fourteen weeks. These same authors showed that the self-annealing temperature of ETP copper strip was a function of prior cold work as well as grain size and orientation. Thus, results of creep studies made on hard drawn wire materials such as those studied by Phillips and Smith cannot be applied to moderately cold worked material which is of interest in this investigation. Inasmuch as creep of copper below the recrystallization temperature also is a function of prior cold work, only data obtained on material in the condition in which it will be used represent valid design parameters.

The ASTM Compilation of Elevated Temperature Properties of Coppers and Copper-Base Alloys[1] presents creep and creep-rupture data for several coppers and copper alloys at temperatures higher than 300 Deg F. These materials include deoxidized copper, OFHC copper, tough pitch copper and a variety of other copper alloys. The temperature range covered by this compilation is substantially higher than that of interest here, however.

Boyd[4] performed experiments on 0.204 in. dia. hydrogen annealed ETP copper wire, in the temperature range of interest. However, the maximum duration of his tests was only 100 hours which is much too short a period of time for a proper prediction of 40-year life.

E. A. Davis[6] has shown that in the temperature range 80°C to 235°C the creep properties of oxygen free copper are significantly improved over those of tough pitch copper, but did not suggest any reason for this improvement. Similar observations were made relative to improved stress-relaxation behavior of oxygen free copper as compared to tough pitch copper by Fox and Swisher in the temperature range 73°F to 200°F. These authors held that oxide inclusions act as stress raisers which accelerate the creep rate.

McAdam Jr. *et al.*[15] presented a general view on the influence of strain rates and temperatures on the mechanical properties of cold drawn oxygen free copper at temperatures ranging from -188C to temperatures approaching the melting point (1083C).

Schwope *et al.*[19] made a study of the comparative creep properties of ETP and OFHC copper wire with and without silver. The maximum silver content studied was 25oz/ton. Although these authors found that softening (as a consequence of recrystallization and grain growth) occurred simultaneously with creep at the higher temperatures, the bulk of their experiments was conducted at 572 Deg F (300°C) and for relatively short time durations. These authors did conduct some limited long-time experiments, but only on OFHC copper containing 15oz/ton of silver. These authors found that cold work as well as adding silver improved the creep strength of copper. This improvement is lost, however, at temperatures above the recrystallization temperature. They found the latter to vary with the amount of cold work and the type of copper. They further found that the addition of silver raised the recrystallization temperature of either tough pitch or ETP copper. The effect was found to be approximately the same in both types of copper.

For copper having been given modest amounts of cold work such as the material studied, the softening temperature was raised from about 450F to 650F. Decker and Harker[7] have expressed the rate of softening as:

$$\text{Softening Rate} = Ae^{-\frac{Q}{RT}} \quad \text{where:}$$

Q = activation energy for recrystallization

R = universal gas constant (1.986 cals/degree C)

T = absolute temperature

A = constant

These authors found that the purity of copper was of prime importance in affecting the value of this activation energy. These authors found a value of Q of 22.4 Kcal/mole for high purity copper (99.999+) as contrasted to 29.9 Kcal/mole for 99.98 percent pure copper. Finlay[7] has calculated the value of Q for 25oz/ton silver bearing copper to be 49 Kcal/mole of copper. This same author attributes this strengthening effect to pinning of grain boundaries by solute atoms (possibly also impurities).

Benson et al.[2] did conduct long-time creep experiments of ETP and OFHC copper strip in the temperature range 130°C to 225°C with and without silver. The maximum silver content studied by these investigators was about 30oz/ton. Wire, however, which is of interest here, has an entirely different texture and residual stress-distribution from strip because of the different fabricating processes involved.

A characteristic pattern of strain is associated with each particular deformation geometry. While the deformation texture (or preferred orientation) of a sheet is described by the crystallographic planes parallel to the surface of the sheet as well as the crystallographic direction parallel to the direction of rolling, in an ideal wire texture a definite crystallographic direction lies parallel to the wire axis and the texture is symmetrical around the wire axis. In face centered cubic metals such as copper the grains have usually $\langle 111 \rangle$ parallel to the wire axis and have random orientation around the axis. In face centered cubic metal strip, by contrast, the texture may best be described by the $\{123\}$ planes lying parallel to the plane of the sheet with the $\langle 112 \rangle$ direction parallel to the rolling direction[20]. It was shown by Fox[9] that the stress relaxation properties of phosphor bronze strip were significantly affected by preferred orientation. Because these differences in preferred orientation between wire and strip affect the creep process and also because the temperature range covered by Benson *et al*. was higher than that of interest here, their findings could not be applied to the problem at hand.

Hodge[13] conducted creep-rupture tests at 550°F (288°C) on silver-bearing copper containing up to 30oz of silver per ton and a very limited amount of creep data was obtained by Finlay[7] on copper containing 60oz of silver per ton at a temperature of 437 Deg F (225°C).

It thus would appear that none of the previous work is directly applicable to the problem at hand, that is how silver additions of up to 60oz/ton affect the time temperature-stress (strain) relations of moderately cold worked silver bearing copper wire at temperatures ranging from 73F to 250F. It might be added at this point that the price of silver bearing copper is directly related to silver content, and it is hoped that from this study designers will be able to balance cost vs reliability in addition to being able to predict material behavior.

MATERIALS STUDIED

To permit a systematic study of the effect of oxygen content and silver addition on the stress-relaxation and creep behavior of copper the following materials were obtained:

1. High purity certified (99.999^{+} percent Cu) copper.
2. High purity (99.999^{+} percent Cu) deoxidized copper containing 25oz/ton of silver.
3. Magnesium deoxidized silver bearing copper containing:
   a) 25oz/ton of silver
   b) 40oz/ton of silver
   c) 60oz/ton of silver
4. ETP silver bearing copper containing:
   a) 25oz/ton of silver
   b) 60oz/ton of silver
5. Commercial OF Copper (CA102)
6. Commercial ETP Copper (CA110)

The chemical composition and mechanical properties of all the materials investigated are shown in Tables I and II respectively. The processing history is shown in Table III.

METHODS OF TEST

The tensile properties (Table II) were determined at room temperature using the test method shown in ASTM Designation: E-8 "Standard Methods of Tension Testing Metallic Materials." The values shown in Table II represent the average value for 5 specimens tested. Jaw breaks were discarded. The jaw separation immediately prior to failure was used to compute percent elongation after subtracting off the very small elastic strain component.

Tensile creep tests were made using 50-in. (1.270m) extensometers for the room temperature experiments and 36-in. (0.914m) extensometers for the elevated temperature studies. These extensometers are similar to those used by Phillips and Smith and are shown in Fig. (4). The wire specimen is loaded with dead weights. A small tubular ferrule is cemented onto the specimen and the separation of this ferrule from a base reference edge on the gage tube is measured as a function of time. A small preload is put onto the wire initially, to insure its tautness when measuring the initial length. This preload produces a tensile stress substantially below the specimen's yield strength, and does not produce any permanent deformation prior to the application of the major load.

Stress relaxation tests were made in tension using a vibrating string technique similar to that described by Gohn and Fox[12]. This technique is illustrated in Fig. 5. It uses the principle that the natural frequency of a vibrating string fixed at both ends is a function of the tension in the string. The two are related by:

$$f = \frac{n}{2L} \sqrt{\frac{T}{\mu}} \quad \text{where:}$$

f = natural frequency

n = number of harmonic (the fundamental = 1)

L = nodal length

T = tension

μ = line mass density

The wire specimen is loaded with dead weights to the desired initial stress and then restrained by the lower clamp to a constant total strain. A U-shaped permanent magnet made from Alnico-5 is mounted on the loading frame in such a way that the specimen being measured is parallel to the pole faces and centrally located in the air gap of the magnet. An alternating electromotive force is then applied to the test specimen by means of a precision oscillator which varies with the magnetic field in accordance with the fundamental physical relation:

$$F = IL \times B$$

where:

F = electromotive force

I = alternating current

L = length of specimen and

B = magnetic field intensity

Driven by this force the specimen vibrates in the plane of the air gap. When the frequency of the driving force corresponds to the resonant frequency of the stressed wire specimen, the latter vibrates at the maximum amplitude. This is determined optically by means of a microscope equipped with a filar eyepiece. The precision oscillator is used not only to drive the test specimen but also to measure the resonant frequency from which the value of the tensile stress may be determined. Replicate test specimens were used for each test condition. Creep tests were made at three temperatures; 73F, 200F and 250F. Stress-relaxation tests were made at 200F. All of the elevated temperature tests were made in gravity convection furnaces, built to accommodate the creep and stress-relaxation apparatus. Temperature control was within ±2deg F.

All tests were made at stresses corresponding to the yield strength (measured at room temperature) at the

0.01 percent offset and at 10.0 ksi. While, in general, design stresses are below the yield strength, designs such as those shown in Fig. 3 require an initial plastic deformation and an associated high stress which relaxes rapidly to a lower stress. In this respect data obtained at the yield strength provide valuable information.

TEST DATA

The creep test data for the materials investigated are shown in the form of creep strain vs time curves in Figs. 6-8. Computer printouts showing individual measurement values, values of the computed creep strain, and curves fitted to these creep strains by a least-square fitting technique printed out by the computer are shown in Appendix 1. The stress-relaxation test data are shown in the form of relaxation curves in Figs. 9-11. As in the case of the creep data, printouts of the individual stress-relaxation data are shown in Appendix 1. An explanation of the various printouts is given in Appendix 1, as well as a description of the fitting techniques used.

DISCUSSION OF THE DATA

Creep

Spectrographically pure (99.999+) percent copper wire was included in this study in order to provide a better insight as to how the addition of silver improves the resistance to creep and stress relaxation. The levels of impurities present in ordinary tough-pitch and oxygen-free coppers (Table 2) would tend to somewhat obscure these strengthening mechanisms. The photomicrographs shown in Fig. 12 clearly indicate that when spectrographically pure copper was stressed to its room temperature 0.01 percent offset yield strength, grain boundary separation occurred which resulted in microcrack formation. These microcracks act as stress raisers which increase the stress level in the area immediately adjacent to the crack. This results in third stage creep and final failure. The creep curves shown in Fig. 6 indicate that, at stress levels as low as 10.0 ksi, third stage creep is reached relatively rapidly at 250deg F in high purity copper. When the initial stress was the 0.01 percent offset yield strength, third stage creep was reached in this material even at 200F. The addition of 25oz of silver per ton to this material, however, resulted in considerable improvement in creep resistance.

Two specimens of the high purity, silverless copper failed in less than 150 hours when stressed to only 19.7 ksi at 250F. No failure could be induced in the silver-bearing high-purity copper at this temperature and time at a stress level of 30 ksi, i.e., a 50 percent higher stress level than that at which the silverless copper had failed. Intercrystalline failures, similar to those observed in the photomicrograph shown in Fig. 12 were observed by Benson *et al.* on both OFHC and ETP silverless and silver-bearing coppers. Their observations, however, were made at 225°C (437F). These same authors observed that ETP copper, cold worked 50 percent, recrystallized at 130°C (266°F). To determine whether the same type of failure mechanism, that is grain boundary separation with ensuing micro-crack formation, occurs in silver-bearing copper at the lower temperatures of interest in this investigation, photomicrographs were obtained on a specimen of high-purity copper containing 25oz per ton of silver, stressed to 33.0 ksi at 250 deg F (122C). It is seen from Figs. 13 and 14 that the grain size of the silver bearing copper is considerably finer than that for the silver-free copper (in the order of 0.010 mm dia.).

Benson *et al.*[2] studied the effect of grain size and cold work on creep of silver-bearing tough pitch copper containing 25oz of silver per ton. These authors found, that for a stress of 14.0 ksi and at a test temperature of 175 Deg C the creep in material having an intermediate grain size (0.023 mm) was almost twice that in material having a coarse grain size (0.043 mm), for amounts of cold work ranging from 5 to 20 percent reduction in area. An explanation offered by Finlay[7] of this relationship (which is opposite to that prevailing at lower temperatures at which it has long been established that "the finer the grain size, the stronger the metal") is using the concept of the "equicohesive temperature". This is defined as the temperature range at which the grain boundaries become weaker than the interior of the grains, so that fracture occurs in an intergranular, rather than a transgranular fashion. Grain boundary sliding occurs at higher temperatures and at longer time application of the load. Fine grain material has, generally, a higher creep strength than coarse grain material at temperatures below the equicohesive temperature. The converse is true at temperatures above the equicohesive temperature. A grain boundary in copper has a high surface energy (about 600 ergs/cm^2). This usually results in a higher concentration of solute atoms at the boundary, rather than at the interior of the grain. Slip lines generally stop at grain boundaries. This together with the requirement for continuity between grains during deformation produce pile-ups of dislocations at the grain boundary. The silver atom is about 14% greater in diameter than the copper atom. The grain boundary region accommodates the larger silver atoms more easily and, since silver diffuses relatively slowly in copper it is believed to pin dislocation pileups at the latter. No evidence could be shown of this, using the conventional microscopy techniques (Figs. 13 and 14) and also microprobe analysis. It is hoped, however to substantiate the above hypothesis through electron-transmission microscopy in future work. Thus while finer grain size appears to affect the creep rate adversely at "high" temperatures and favorably at "low" temperatures it is believed that the main contribution toward strengthening of the copper by the silver addition is due to the associated increase in the recrystallization temperature.

Figure 7 shows creep curves for the magnesium deoxidized copper with various levels of silver and Fig. 8 shows similar curves for electrolytic tough-pitch copper. A fundamental comparison of the mechanical behavior of oxygen-free and tough-pitch coppers was presented by Opie, Taubenblat and Hsu.[16] These authors found that in tough-pitch copper, Cu_2O stringers act as voids which serve as stress concentrations when the material is subject to cold working. This appears also to be true in the case of creep at the temperatures of interest. Figure 15 shows typical fractured surfaces of ETP and OF creep specimens, which failed after 0.2 hours at 33 ksi and 250 deg F. It is evident from Fig. 15 that the oxygen-free copper has a smooth cup-cone fracture and deforms rather uniformly. The cracks in the ETP copper specimen, by contrast, appear to initiate in the oxide stringers which are clearly visible and which act as stress-concentrations.

In general, it can be said that the creep rate in the tough-pitch copper is somewhat higher than in OF copper thus confirming the findings of Opie *et al*. This appears also to be true after the addition of silver, although to a lesser degree.

From Fig. 7, it may be seen that the creep strain in oxygen-free copper is approximately twice that in silver-bearing material containing 25oz Ag/ton and four times that in silver-bearing material containing 40oz Ag/ton. No substantial further improvement is achieved when increasing the silver addition to 60oz/ton.

A fundamental description of the creep curve as well as various creep laws proposed by numerous authors may be found in the references by Rabotnov and Hult.[18,14] It is rather obvious from the previous discussion of the microstructural observations made on some of the materials tested that the phenomenological aspects of the problem are, indeed, extremely complex. Sound engineering practice requires, however, that the designer be able to make rapid quantitative, though approximate estimates of how the performance of the final product will be affected by the various parameters. Such estimates require that these parameters be expressed in simple mathematical terms, regardless of the phenomenological complexity. Such simple models for describing the creep relations may be found in Hult and Rabotnov. An illustration of the "typical" creep curve will, however, be helpful in the discussion which follows. Such a creep curve is shown in Fig. 16.

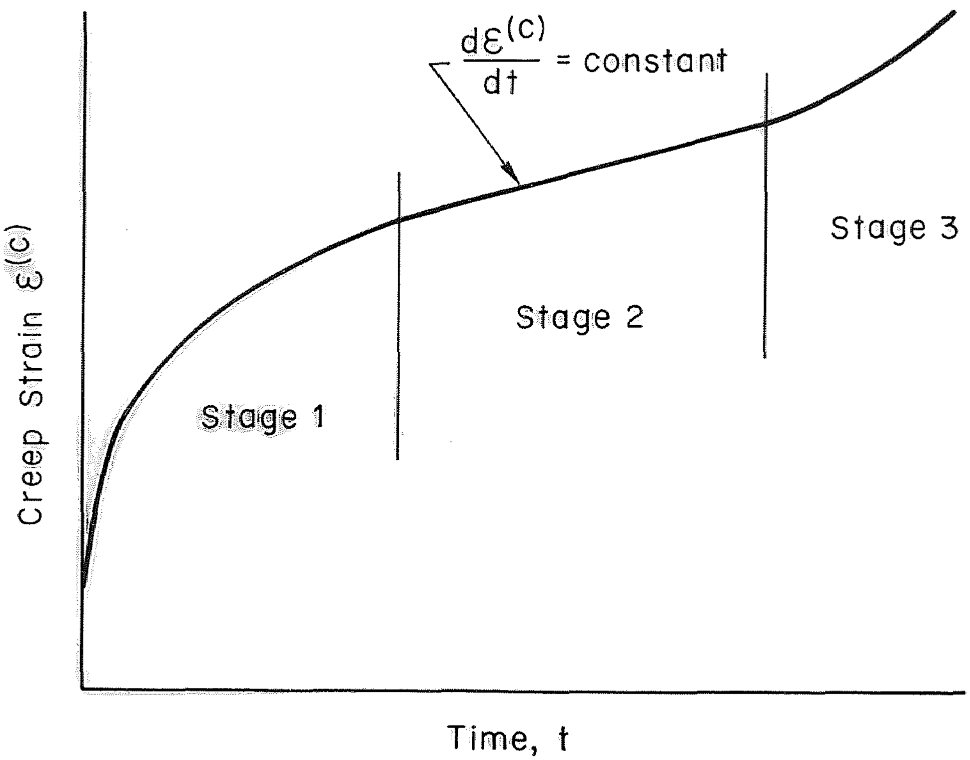


FIG. 16 TYPICAL CREEP CURVE.

The creep strain may be expressed as a function of stress, time and temperature.

$$\varepsilon_c = f(\sigma, t, T) \;\ldots\ldots\ldots \quad (1)$$

The creep rate may be written as:

$$\frac{d\varepsilon_c}{dt} = g(\sigma, t, T) \;\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$ where:

$g(\sigma,t,T) = \frac{\partial f}{\partial t}$ since σ and T are constant.

This leads to:

$$\frac{d\varepsilon_c}{dt} = h\;[\sigma, \varepsilon_c, T] \;\ldots\ldots\ldots\ldots (3)$$

The fact that the creep rate depends on the creep strain may be attributed to strain hardening effects. Equation 3 was expressed as a simple power expression by Norton and Bailey (see Hult) where:

$$\frac{d}{dt}\;[\varepsilon_c]^{1+\mu} = \frac{1+\mu}{\tau}\left(\frac{\sigma}{\sigma_m}\right)^m \;\ldots\ldots\ldots\ldots\ldots (4)$$ where:

τ = a fixed time unit chosen to represent the time required to produce a given creep rate.

μ, m and σ_m are material parameters which may be determined experimentally (see Appendix 2). The quantity μ is sometimes termed a strain hardening exponent and reduces to zero for secondary creep so that:

$$\frac{d\varepsilon_c}{dt} = \frac{1}{\tau}\left(\frac{\sigma}{\sigma_m}\right)^m \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

It should be emphasized that all of these expressions are based on the principle of a linear creep law and break down when the strains are no longer linear functions of the stress, temperature and time.

Stress Relaxation

The stress-relaxation data for the materials investigated are plotted in Figs. 9-11. The remaining stress, expressed as a percentage of the initial stress is shown as the ordinate, the elapsed time, in hours, as the abscissa. Figure 9 shows the effect of silver addition on the stress-relaxation behavior of oxygen-free copper. As in the case of creep, the resistance to stress relaxation increases directly with silver content. It is interesting to note that the difference in resistance to stress-relaxation between tough pitch and oxygen-free copper narrows after silver has been added. Figure 11 shows the effect of silver addition on the stress-relaxation behavior of spectrographically pure copper wire. There appears to be a significant stress dependency. It is also seen that, while in the case of creep, spectrographically pure copper exhibited the highest creep rate, in the case of stress relaxation this is no longer true. ETP copper, for example, relaxes more than spectroscopically pure copper at both stress levels used. The latter material showed considerably higher creep, however, than tough-pitch copper. This last observation clearly indicates that attempts to apply a mechanical equation of state to obtain creep data from stress relaxation tests and vice versa are doomed to failure for the type of materials studied here. Considering, for example, the microcracks shown in Fig. 14 it is obvious that the creep rate will be governed by the frequency and lengths of those cracks, in the case of a constant load creep test; in the case of stress relaxation, however, the cracks are not permitted to grow and hence the respective rate processes cannot be correlated by methods other than curve-fitting.

CONCLUSIONS

Substantial improvement in resistance to creep and stress relaxation was observed in the temperature range 73F to 250F when adding silver to copper conductor. This improvement is believed to be primarily due to strengthening of the grain boundary region due to pinning of boundaries by solute silver which is also believed responsible for the increase in recrystallization temperature. The addition of silver also made it possible to produce a much finer and more uniform grain structure. No attempt has been made in the course of this investigation to correlate creep and stress relaxation. However, on the basis of the metallographic observations which indicate the presence of local stress concentrations at microcracks producing a variable rather than a constant stress state as a function of time on a micro-scale and on the basis of strain hardening considerations, such a correlation would only appear possible at low stresses and temperatures, i.e. where stress and strain may be expected to be linear functions of time at any temperature.

RECOMMENDATIONS

It is suggested on the basis of this work that electron-transmission microscopy studies be made of the grain boundary region to verify the hypothesis offered in this thesis, namely that impurities or silver particles pin dislocation pileups at the grain boundary thus strengthening the material. After the accumulation of about 10,000 hr of data, the relation between minimum creep rate, the activation energy for creep and temperature should be established. On the basis of the data presented here, it is recommended that either ETP or OF copper with a minimum addition of silver of 25oz per ton be used for applications such as Main Distributing Frame wiring, that is for applications where the temperatures do not exceed 200 Deg F and where a moderate amount of stress-relaxation can be tolerated (less than 50 percent in 40 years).

ACKNOWLEDGMENTS

The helpful advice and guidance of Professor H. Herman, in the preparation of this thesis is greatly appreciated. I gratefully acknowledge the support provided by Bell Telephone Laboratories in this research by permitting use of their laboratory facilities and providing some of the materials studied. My thanks to Mr. P. R. White of Bell Labs for his help in planning this study, to Dr. H. Fisher and the Copper Range Co. for supplying some of the materials investigated, to Mr. K. M. Olsen of Bell Labs for his help in the processing of the materials, to Mr. O'Brien of Bell Labs for his assistance with the photomicrographic work and to Mr. Hal Gorman who wrote the computer programs for the reduction of the creep and stress relaxation data. The helpful suggestions and comments of Professors Pappas and Schneider of NCE and of Messrs. T. D. Schlabach, G. F. Weissmann and L. P. Key of Bell Labs all of which reviewed the manuscript, are also thankfully acknowledged.

Curriculum Vita

Alfred Fox, a native of Vienna, Austria, is currently a member of the Mechanics of Materials Group of the Metallurgical Engineering Department at Bell Labs, Murray Hill, New Jersey. He has received an Associate in Applied Science Degree from New York City Community College and a Bachelor of Science in Engineering from the Cooper Union School of Engineering. He is a member of ASTM Committees E-9 on Fatigue and E-28 on Mechanical Testing.

REFERENCES

1. ASTM STP No. 181, "Elevated Temperature Properties of coppers and Copper Base Alloys", American Society for Testing and Materials, 1956.

2. Benson, N. D., J. McKeown and D. N. Mends, "Creep and Softening Properties of Copper for Alternator Rotor Windings", Journal of the Institute of Metals, Vol. 80, 1951-52, p. 131.

3. Bond, N. T., "Aluminum Contact Surfaces in Electrical Transition Interfaces, "IEEE Transactions on Parts, Materials and Packaging, Vol. PMP-5, No. 2, June 1969.

4. Boyd, J., "The Relaxation of Copper at Normal and Elevated Temperatures", Proceedings, American Society for Testing and Materials, Vol. 31, Part II, 1937, p. 218-234.

5. Cook, M. and T. L. Richards, "The Self-Annealing of Copper," Journal of the Institute of Metals, Vol. 70, p. 159.

6. Davis, E. A., "Creep and Relaxation of Oxygen-Free Copper", Journal of Applied Mechanics, June 1943, p. A-101.

7. Decker, B. F. and Harker, "Activation Energy for Recrystallization in Rolled Copper", Trans AIME Journal of Metals, Vol. 188, p. 887, 1950.

8. Finlay, W. L., Silver-Bearing Copper, Corinthian Editions, 1968.

9. Fox, A., "The Effect of Extreme Cold Rolling on the Stress Relaxation Characteristics of CDA Copper Alloy 510 Strip", Journal of Materials, Vol. 6, No. 2, June 1971, pp. 422-435.

10. Fox, A. and G. J. Herbert, "Aluminum Alloy Conductor for Communications Cable with Superior Creep and Stress-Relaxation Properties, Proceedings, 6th International Conference on Electrical Contacts, Chicago, Illinois, June 1972 (to be published).

11. Fox, A. and J. H. Swisher, "Superior Hook-Up Wires for Solderless Wrapped Connections," Journal of the Institute of Metals, Vol. 100, January 1972, pp. 30-32.

12. Gohn, G. R. and A. Fox, "New Methods for Determining Stress Relaxation", Materials Research and Standards, Vol. 1, No. 12, December 1961, pp. 957-967.

13. Hodge, W., "Some Properties of Certain High-Conductivity Copper-Base Alloys", Journal of Metals, April 1957, p. 405.

14. Hult, J. A., Creep in Engineering Structures, Blaisdell Publishing Co., Waltham, Mass., 1966, p. 21.

15. McAdam, Jr., D. J., G. W. Geil and D. H. Woodard, "Influence of Strain Rate and Temperature on the Mechanical Properties of Monel Metal and Copper", Proceedings, American Society for Testing and Materials, Vol. 46, 1946, p. 902.

16. Opie, W. R., P. W. Taubenblat and Y. T. Hsu, "A Fundamental Comparison of the Mechanical Behavior of Oxygen-Free and Tough Pitch Coppers", Journal of the Institute of Metals, Vol. 98, 1970, p. 245.

17. Phillips, A. J., and A. A. Smith, Jr., "Effect of Time on Tensile Properties of Hard Drawn Copper Wires", Proceedings, American Society for Testing and Materials, Vol. 36, Part II, pp. 263-275, 1936.

18. Rabotnow, Yu. N., Creep in Structural Elements, National Technical Information Service Report No. AD 708356, March 20, 1970 (Translated from the Russian).

19. Schwope, A. D., K. F. Smith and L. R. Jackson, "Comparative Creep Properties of Several Types of Commercial Coppers", Metal Transactions, Vol. 185, July 1949, p. 409.

20. Smallman, R. E., "Textures in Face-Centered Cubic Metals and Alloys", Journal of the Institute of Metals, Vol. 87, 1955-56, pp. 10-18.

LIST OF TABLES

Table 1 - Chemical Analysis of Materials Tested, w/o percent

Material	High Purity Copper	Tough Pitch	Oxygen Free	with 25oz./ton silver			with 40oz./ton silver	with 60oz./ton silver	
				High Purity Copper	Tough Pitch Copper	Oxygen Free Copper	Oxygen Free Copper	Tough Pitch Copper	Oxygen Free Copper
Sb	<0.0001								
As	<0.0002								
Bi	<0.0001								
Fe	<0.00007				0.0029	0.0029	0.0027	0.003	0.0026
Pb	<0.0001								
Ni	<0.0001				0.0079	0.0079	0.0077	0.01	0.0078
O_2		0.0355	0.0013		0.031	0.0001	0.0007	Not checked	0.0006
Se	<0.0001								
Ag	<0.00003	0.001	0.002	0.078	0.083	0.083	0.130	0.196	0.201
S	<0.0001								
Te	<0.0002								
Sn	<0.0001								
Cu	99.999^+	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance
Mg						0.0040	0.0036		0.0039

Table 2 - Mechanical Properties of Conductors Studied: Diameter 0.0201 in. (24 AWG) Cold Reduction: 1/2 B&S Gage

Property*	Tensile Strength,** ksi	Yield Strength at 0.01%	Yield Strength at 0.2%	Elongation, % in 10 in.	Modulus of Elasticity, ksi
Material					
ETP Copper	40.6	17.5	35.5	11.7	$13.0x10^3$
ETP Copper +25oz. Ag/ton	42.8	20.7	39.8	9.5	$12.3x10^3$
ETP Copper +60oz. Ag/ton	45.8	21.4	42.7	1.2	$12.0x10^3$
OF Copper	40.3	20.6	37.8	11.1	$11.8x10^3$
Deoxidized Copper +25oz. Ag/ton	43.6	22.1	41.6	8.5	$12.8x10^3$
Deoxidized Copper +40oz. Ag/ton	44.1	18.7	40.7	4.6	$13.2x10^3$
Deoxidized Copper +60oz. Ag/ton	46.9	24.2	43.7	2.7	$12.0x10^3$
High Purity Copper	40.4	19.7	37.7	3.8	$12.3x10^3$
High Purity Copper +25oz.	44.9	21.6	42.2	4.1	$12.3x10^3$

* All values are the average of 5 determination.

** Jaw breaks were discarded.

Table 3 - Complete Processing History of Materials Tested

1. High purity certified (99.999 percent$^+$) copper.
   a) Obtained from American Smelting and Refining Co., South Plainfield, N. J.
   b) Drawn in several steps to 0.0213 in. dia. by BTL.
   c) Strand annealed in hydrogen atmosphere at 450deg. C at 6 ft. per minute through a 3 ft. long hot zone.
   d) Cold drawn to final diameter of 0.0201 in. (24 gage AWG).
2. High purity certified (99.999 percent$^+$) copper with 0.09w/o percent silver.
   a) Item 1 was cast into ingot by Bell Laboratories Processing Laboratory, 0.09w/o percent silver added.
   b) Further processing followed steps (b), (c) and (d) of Item 1.
3. Magnesium deoxidized, silver-bearing copper (OF)
   a) Obtained from Contemporary Research, Inc., Natick, Mass., after the following processing:
   b) Hot rolled from 1 in. thick x 4 in. wide cast plate to 0.500 in. thick plate; 0.500 x 0.500 in. square section lengths were removed and rod rolled and swaged cold to 0.250 in. dia., annealed 2 hours at 800 deg F (427C) and furnace-cooled slowly in a protective atmosphere.

Table 3 - (Cont'd)

c) Further processing followed steps (b), (c) and (d) of Item 1.

4. Silver bearing, tough-pitch copper

a) Obtained from Contemporary Research, Inc.

b) Cold drawn to 0.100 in. dia.

c) Annealed at 0.100 in. diameter, cold drawn to 0.0213 in. dia.

d) Strand annealed in helium in 3 ft. long hot zone at 500 deg. C and at a speed of 3 ft. per min.

e) Cold drawn to 0.0201 in. dia.

5. Oxygen Free Copper

a) Obtained from Little Falls Alloys, Inc., Paterson, N. J. as hard drawn 0.057 in. diameter wire.

b) Annealed, cold drawn to 0.0213 in. dia.

c) Further processing followed steps (c) and (d) of Item 1.

6. Electrolytic, Tough Pitch Copper

a) Obtained from BTL stockroom at 0.046 in. diameter wire, annealed.

b) Cold drawn to 0.013 in. diameter.

c) Further processing followed steps (c) and (d) of Item 1.

LIST OF FIGURES

CB-70-5912-BA
3-18-70
Case 39057-11

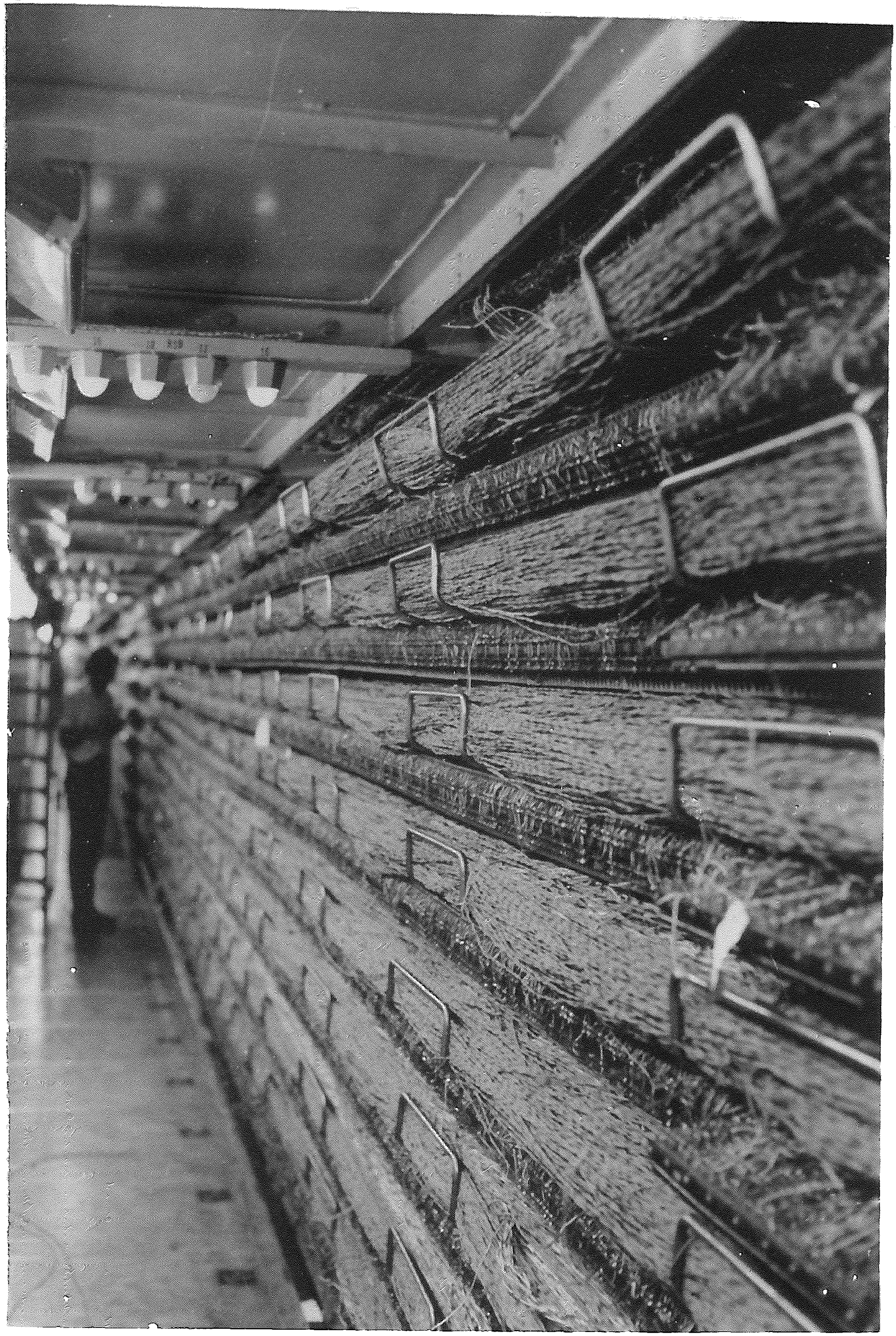


FIG 1 SUBSCRIBER FRAME
HORIZONTAL MDF WITH "HAIRPINS"

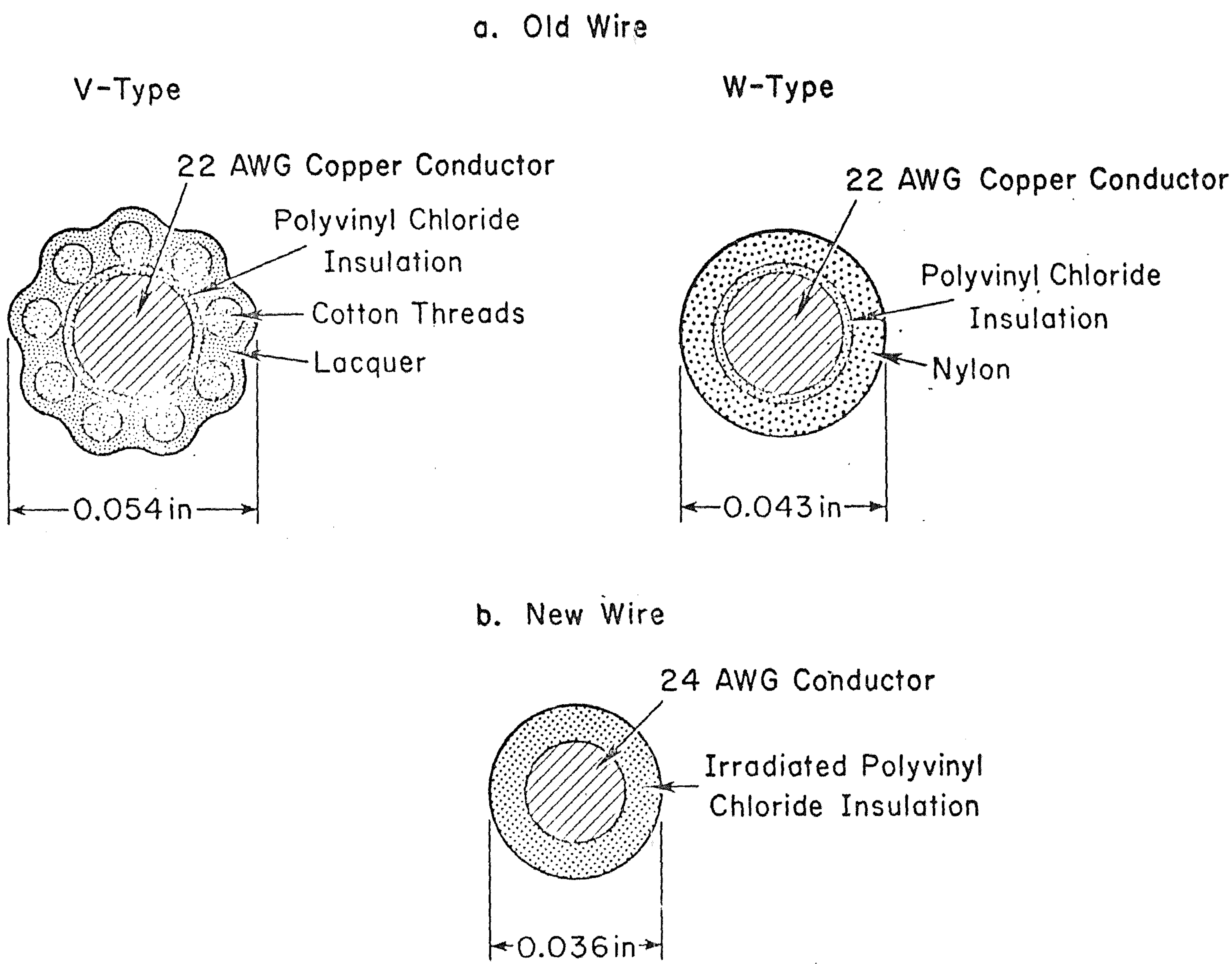
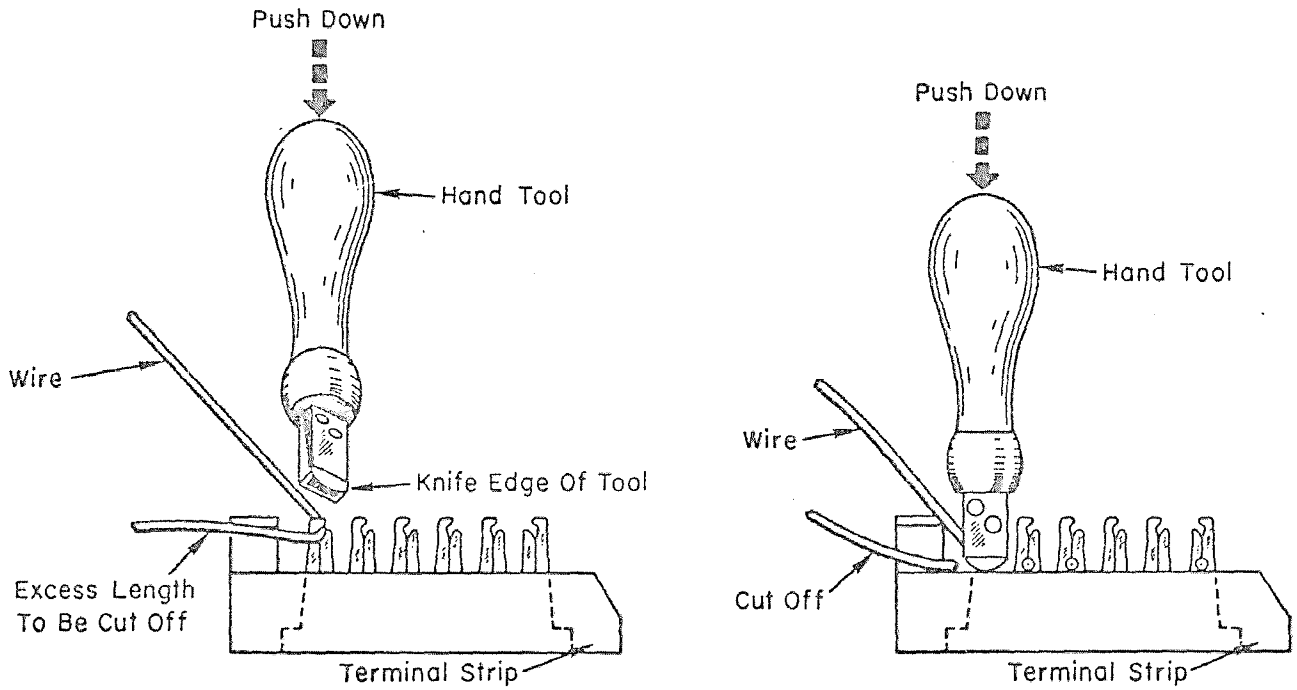
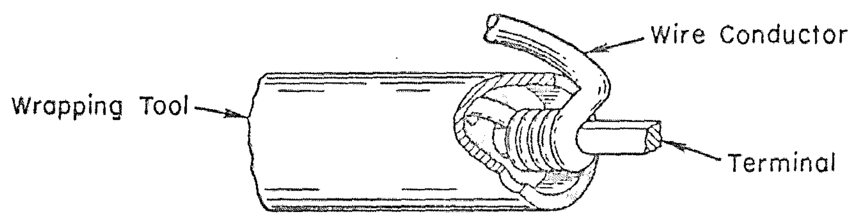


FIG. 2 MAIN TYPES OF DISTRIBUTING FRAME WIRE



(a) Quick Clip Connection



(b) Solderless Wrapped Connection

FIG. 3 SOME PRESSURE-TYPE CONNECTIONS

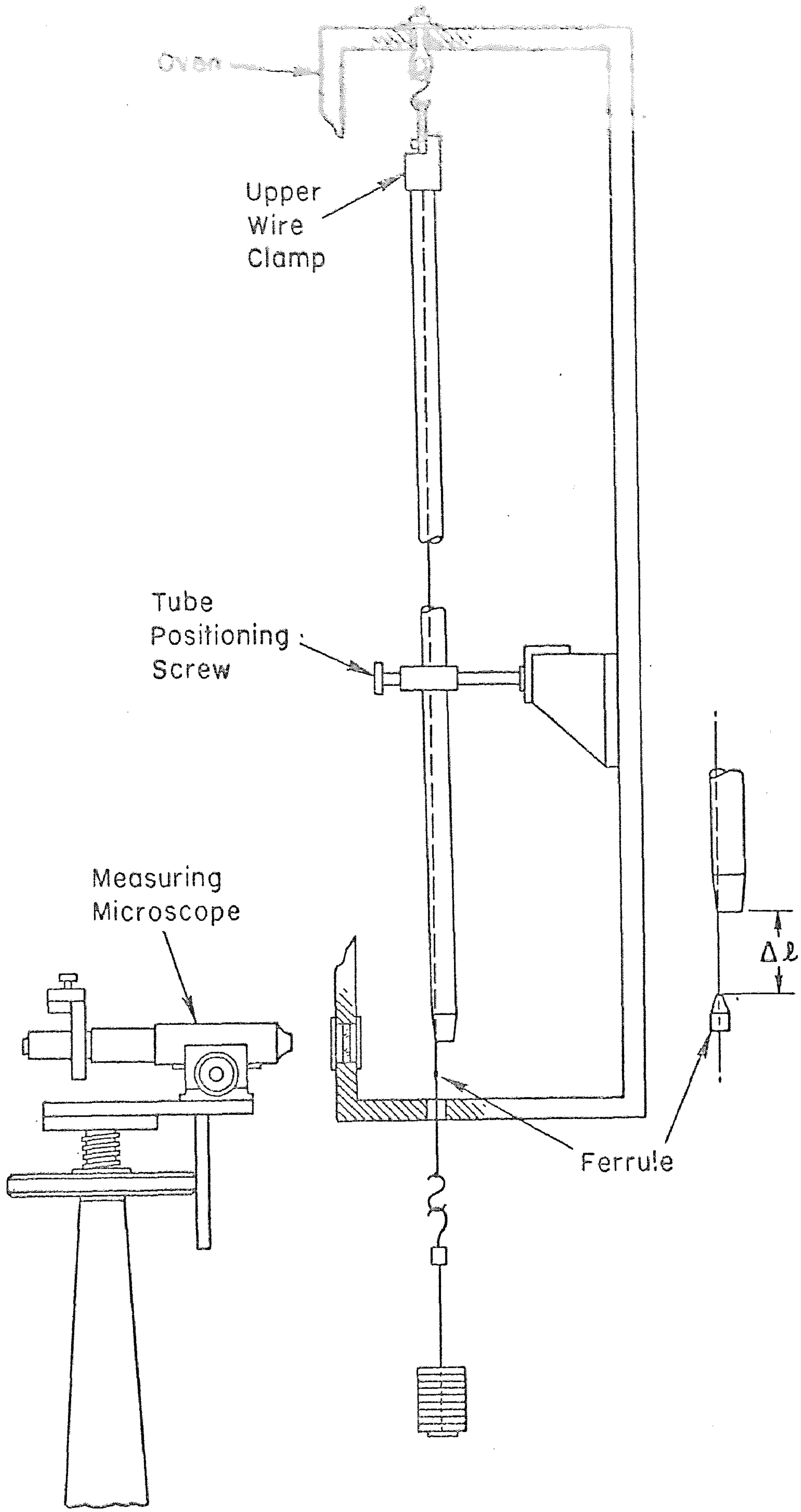


FIG. 4 CREEP APPARATUS

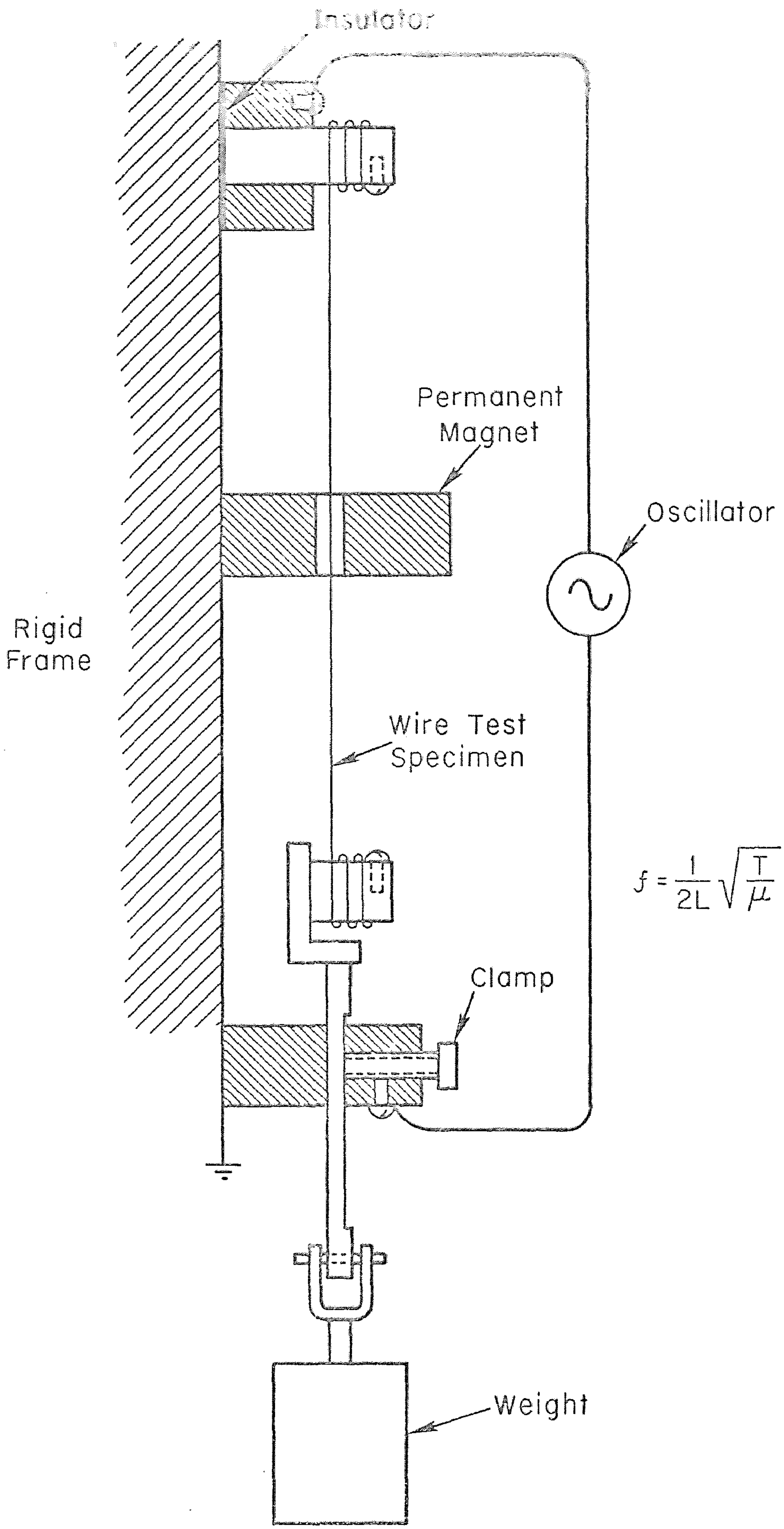


FIG. 5 STRESS RELAXATION APPARATUS

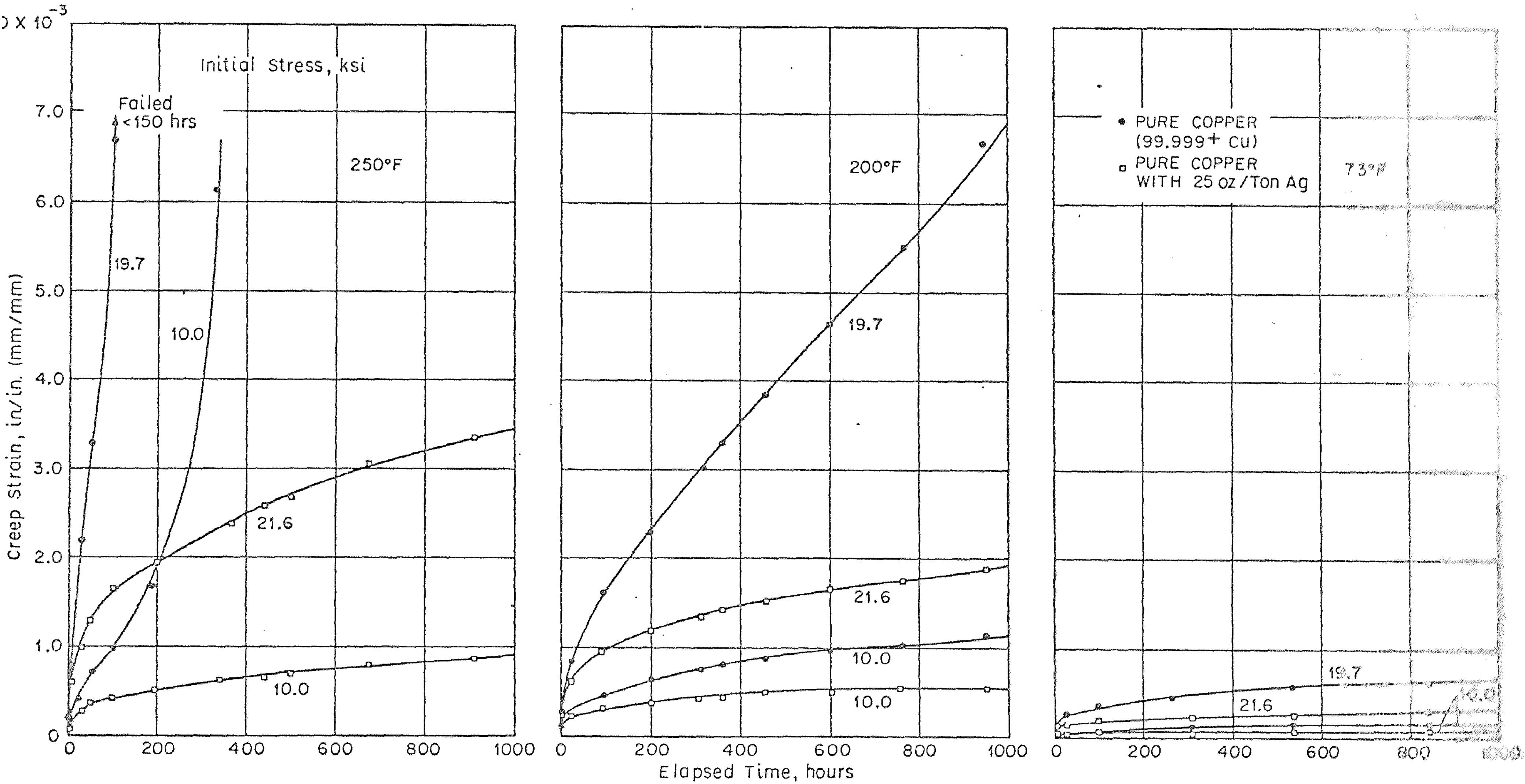
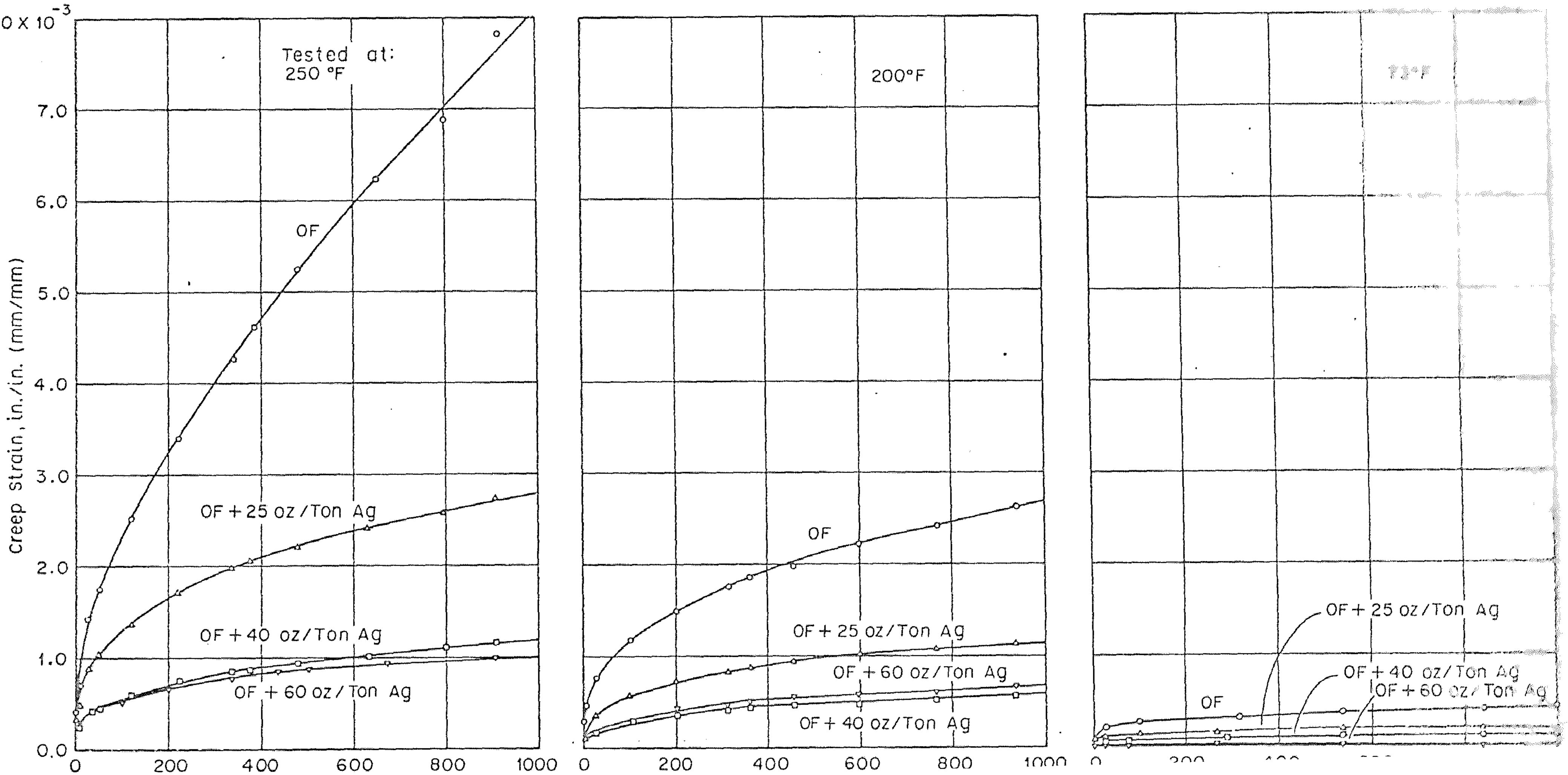
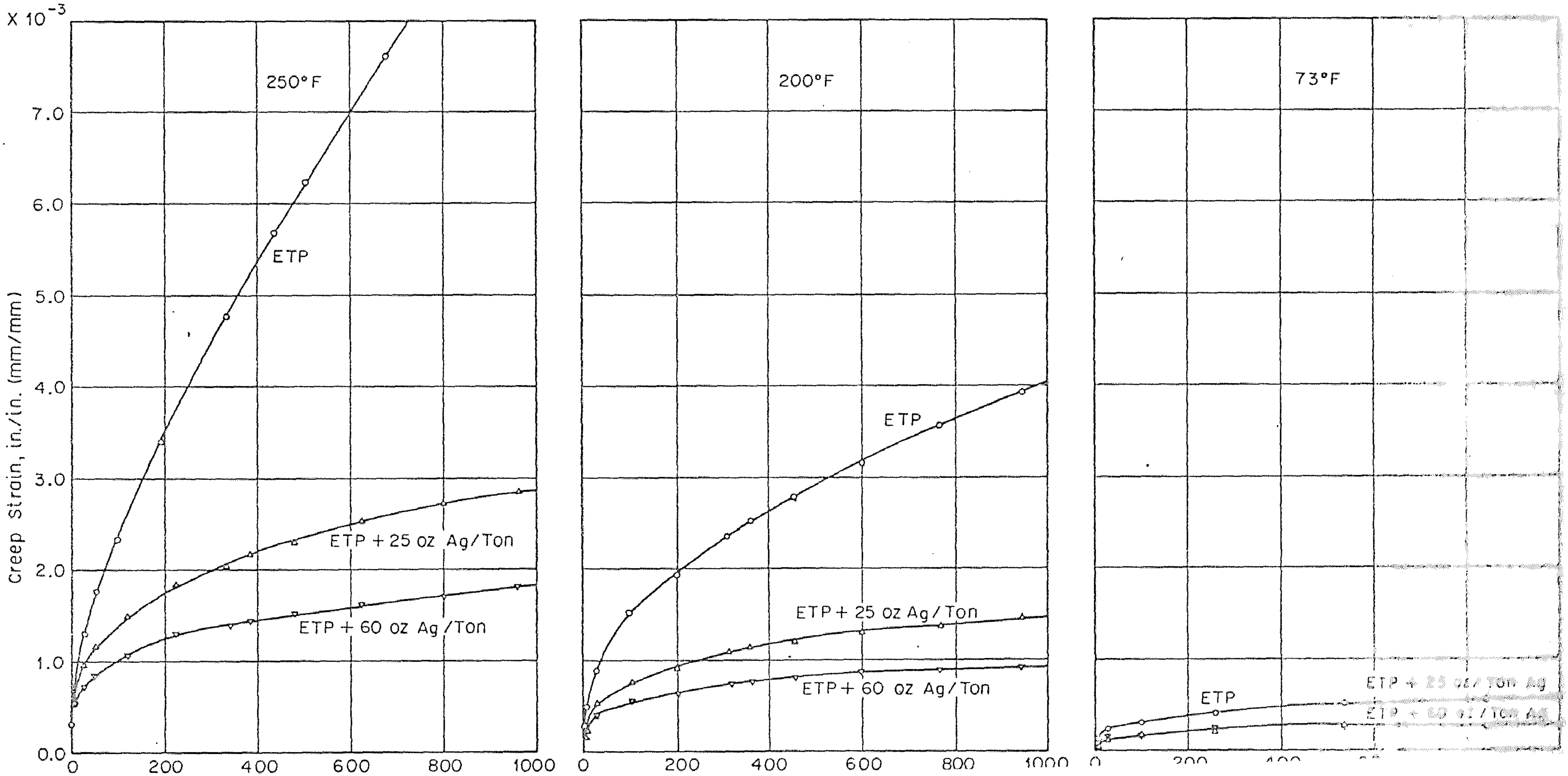


FIG. 6 EFFECT OF SILVER ADDITION (25 oz Ag/Ton of Cu) ON CREEP CHARACTERISTICS OF SPECTROGRAPHICALLY PURE (99.999^+) PERCENT COPPER WIRE

Material: Cold Drawn 1/2 B & S No. Dia. 0.0201 in.



0 X 10^-3
Tested at:
250 °F
200°F
Creep Strain, in./in. (mm/mm)
OF
OF + 25 oz/Ton Ag
OF + 40 oz/Ton Ag
OF + 60 oz/Ton Ag
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
200
400
600
800
1000



X 10^-3
Creep Strain, in./in. (mm/mm)
250°F
200°F
73°F
ETP
ETP + 25 oz Ag/Ton
ETP + 60 oz Ag/Ton
ETP + 25 oz/Ton Ag
ETP + 60 oz/Ton Ag
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
0
200
400
600
800
1000

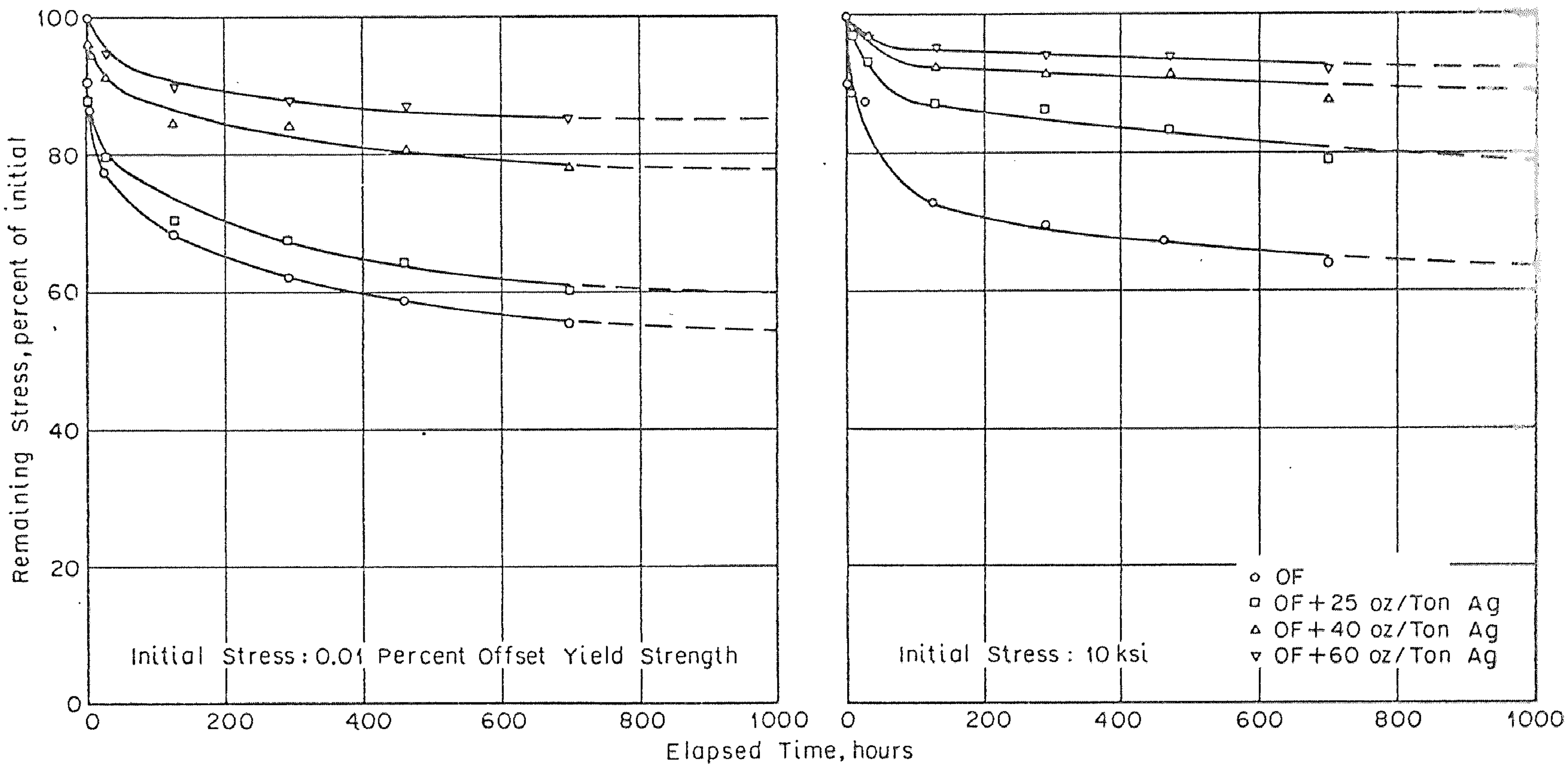


FIG.9 EFFECT OF SILVER ADDITION ON THE STRESS-RELAXATION CHARACTERISTICS OF OXYGEN FREE COPPER WIRE.

Material: Cold Drawn 1/2 B & S No. Dia. 0.0201 in.
Tested at 200°F

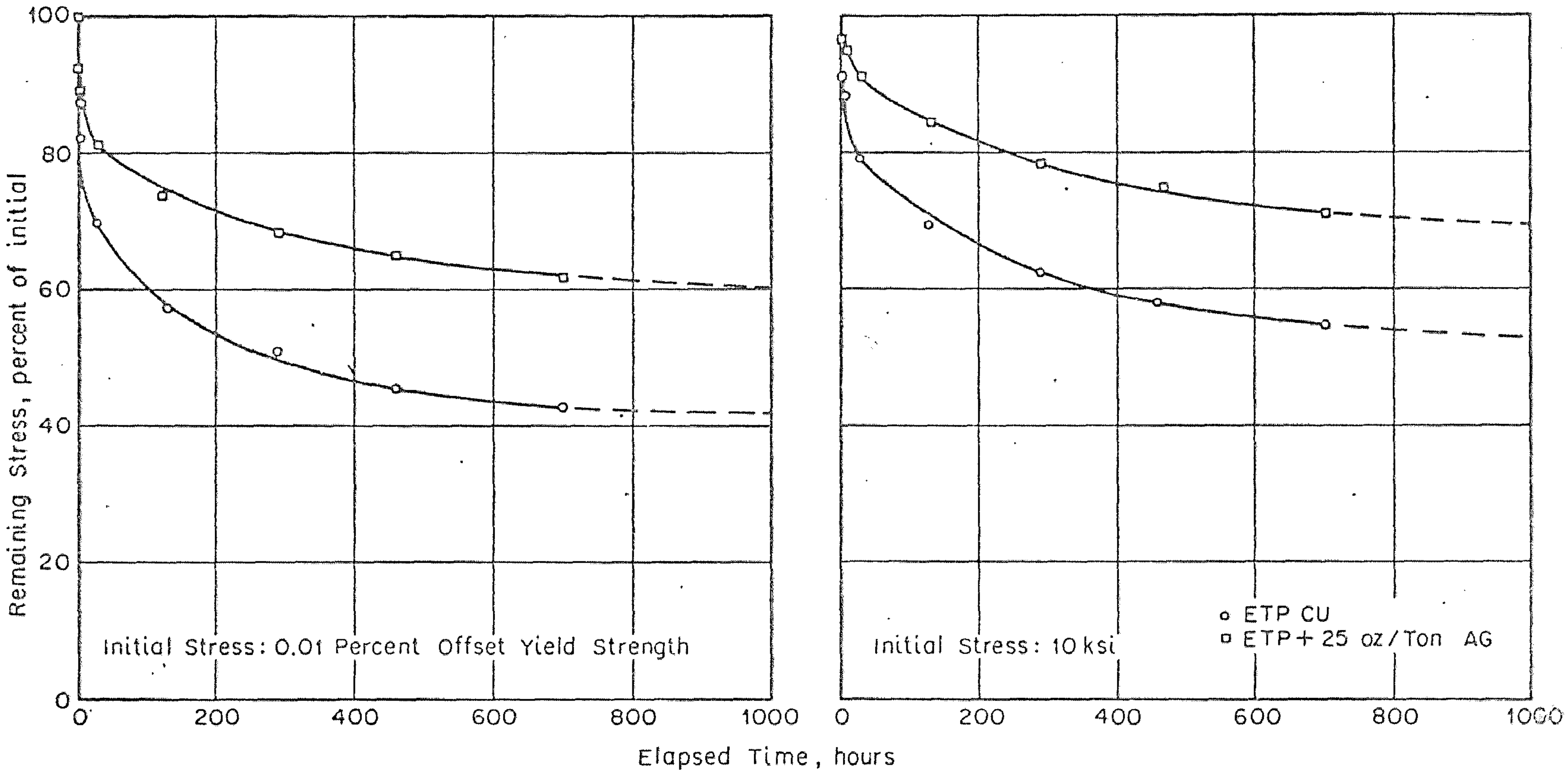


FIG. 10 EFFECT OF SILVER ADDITION ON THE STRESS-RELAXATION CHARACTERISTICS OF ELECTROLYTIC TOUGH PITCH COPPER

Material: Cold Drawn 1/2 B&S No. Dia. 0.0201 in.
Tested at 200° F.

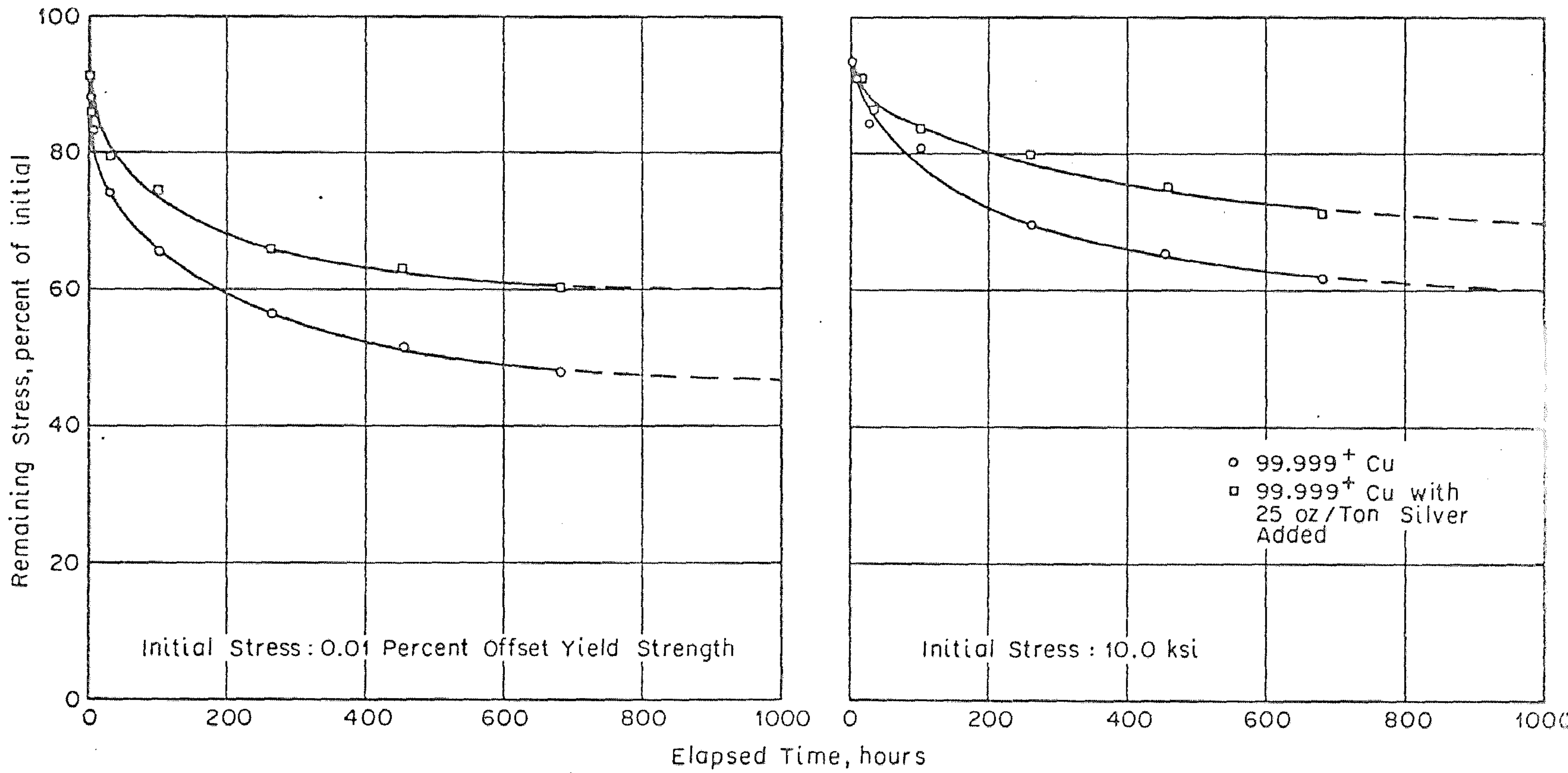
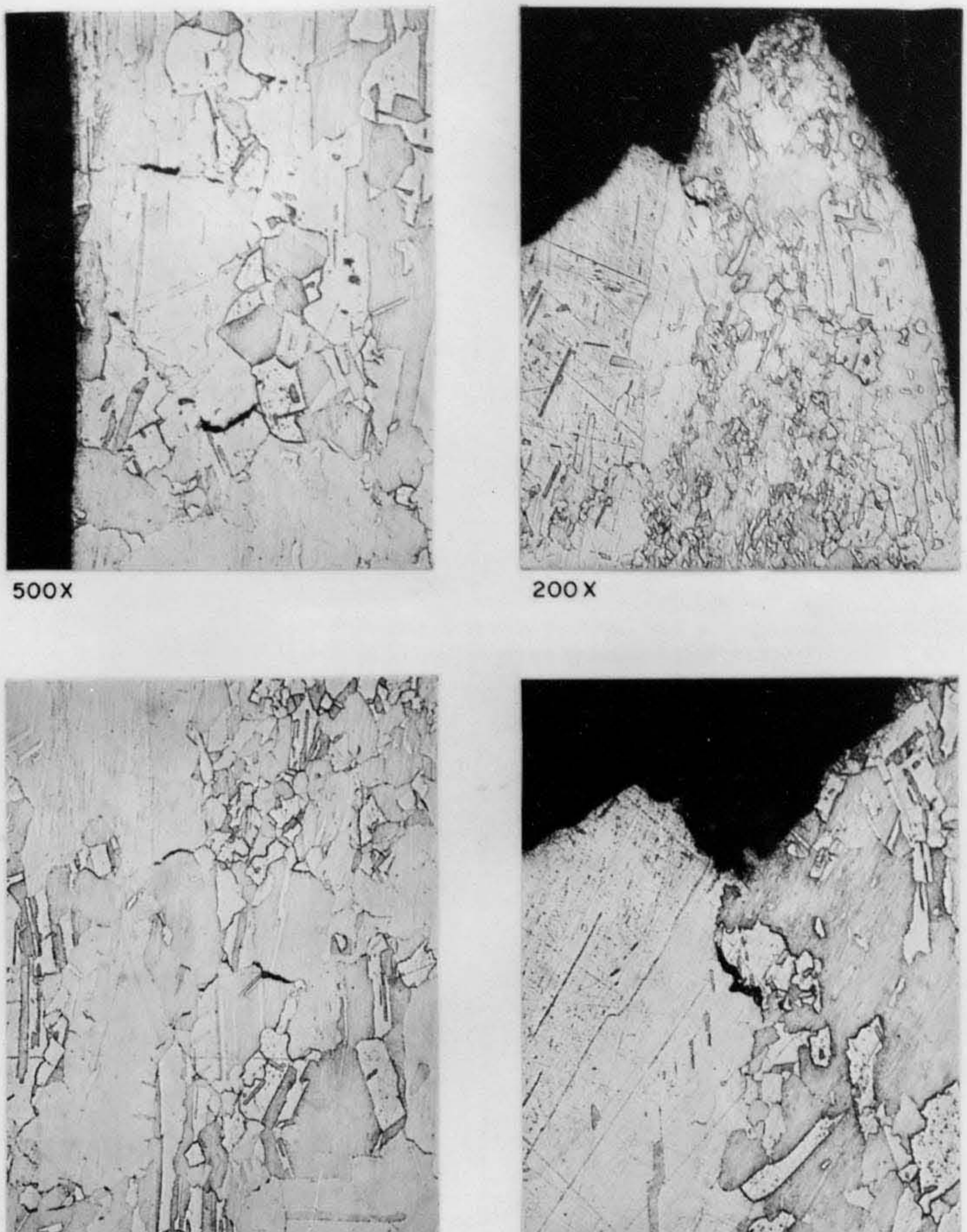


FIG. 11 EFFECT OF SILVER ADDITION ON THE STRESS-RELAXATION CHARACTERISTICS OF SPECTROGRAPHICALLY PURE (99.999^{+}) PERCENT COPPER WIRE.

Material: Cold Drawn 1/2 B & S No. Dia. 0.0201 in.
Tested at 200° F



500X 200X

500X 500X

Typical Grain Boundary Separation Away From Fractured Surface

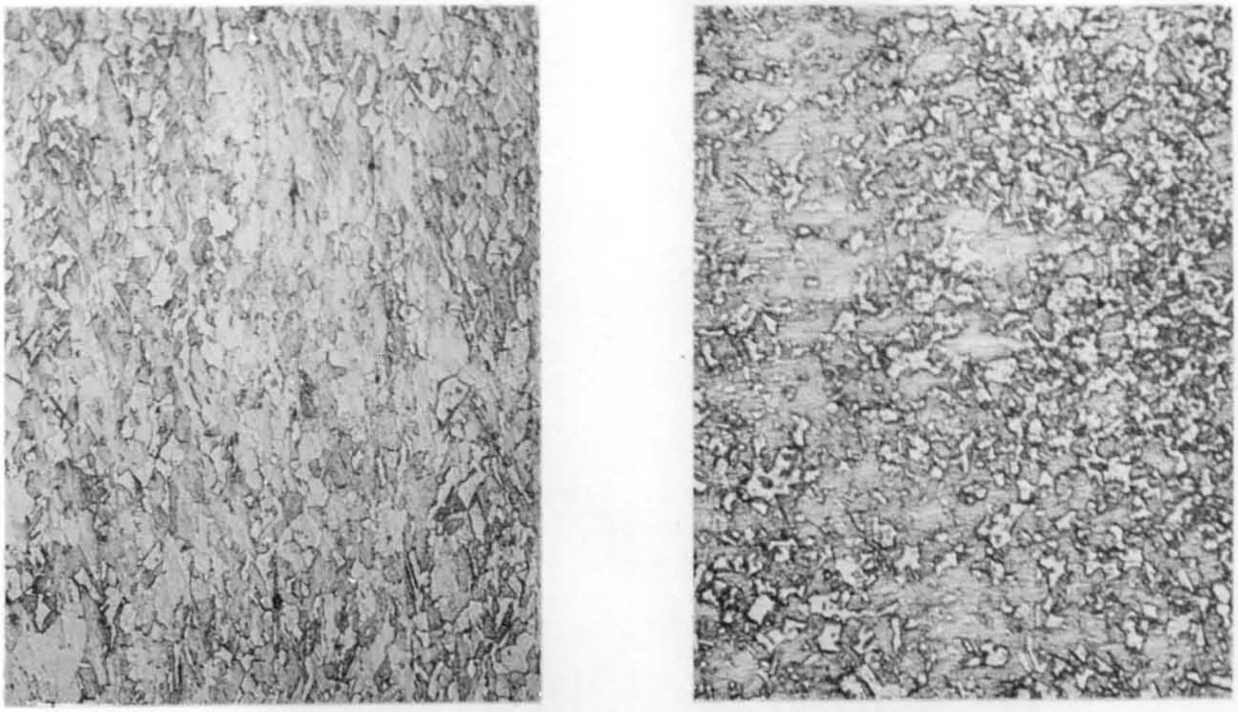
Fractured Surface Longitudinal Section

Stressed to 19.7 ksi at 250 deg F

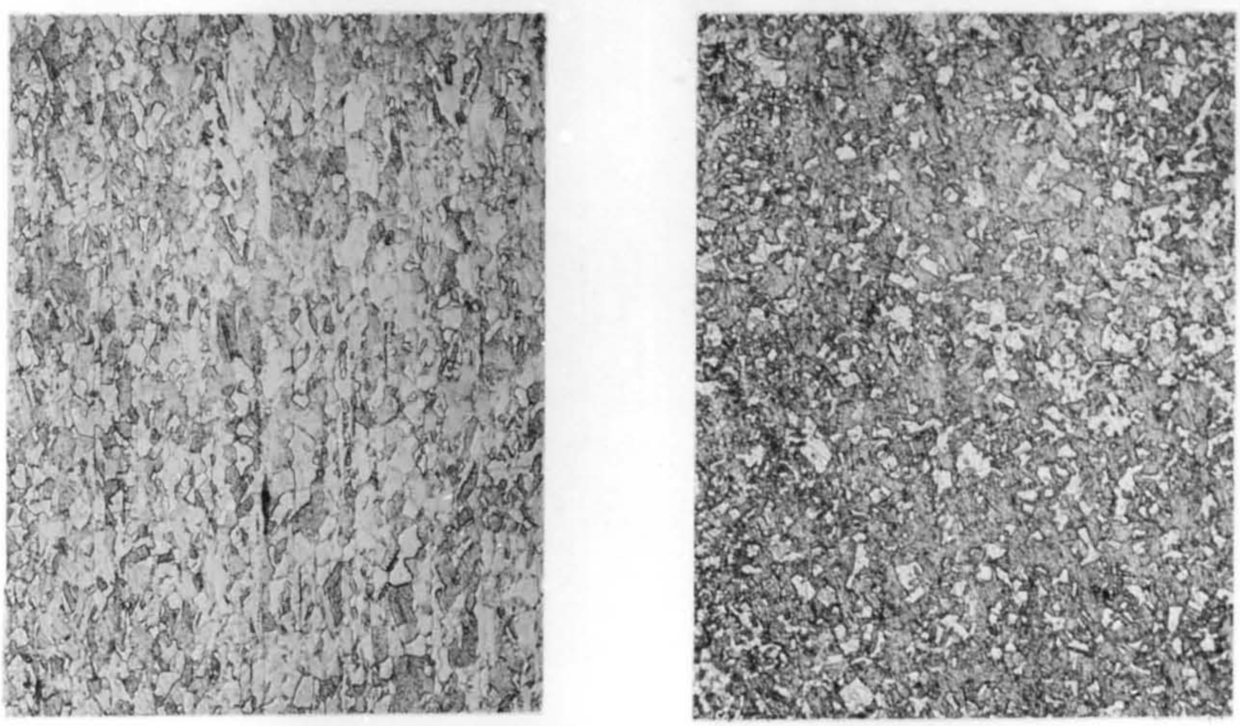
Failed after 150 hr

FIG. 12 GRAIN BOUNDARY SEPARATION AND MICRO-CRACK FORMATION DUE TO CREEP OF HIGH PURITY (99.999^{+}) PERCENT COPPER.

Longitudinal Section Transverse Section



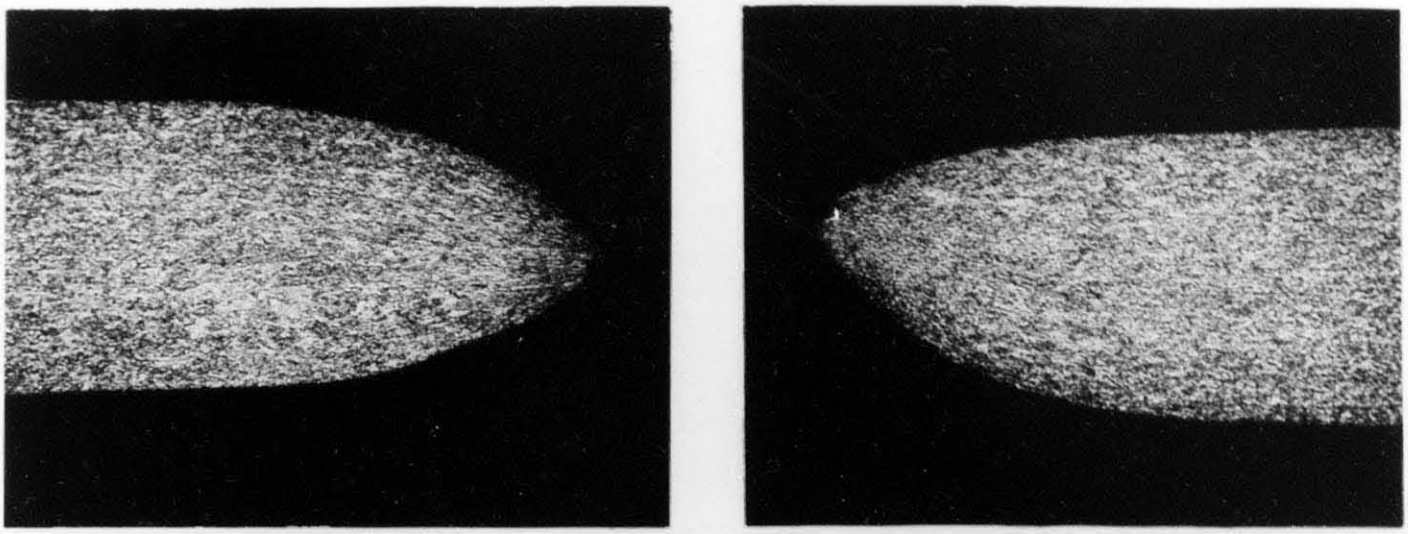
(a) As Drawn



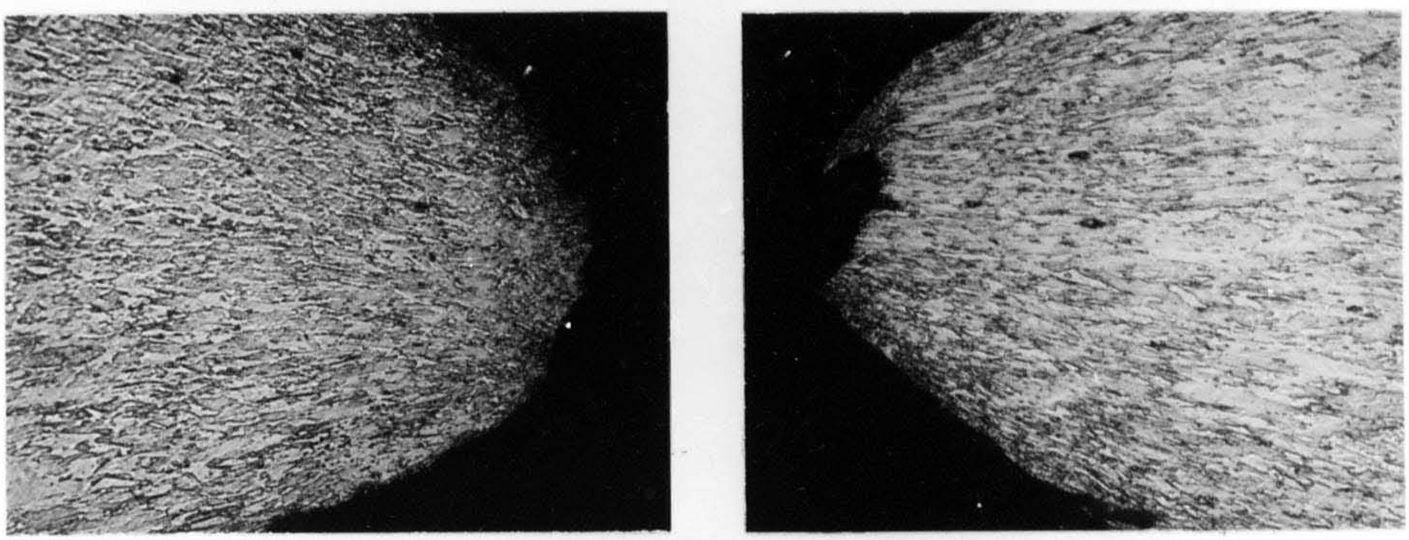
(b) Stressed to 33ksi at 250 deg F
for 9.2 hours. Approximately
3 in. from fractured surface.

Original Magnification: 500X

FIG. 13 EFFECT OF CREEP ON MICROSTRUCTURE OF HIGH PURITY COPPER WIRE WITH 25 OZ PER TON OF SILVER ADDED



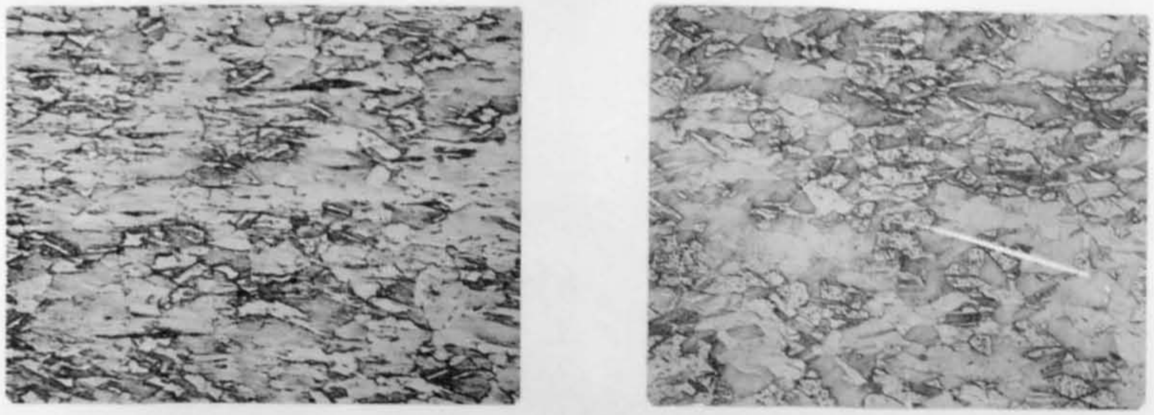
Original Magnification: 200X



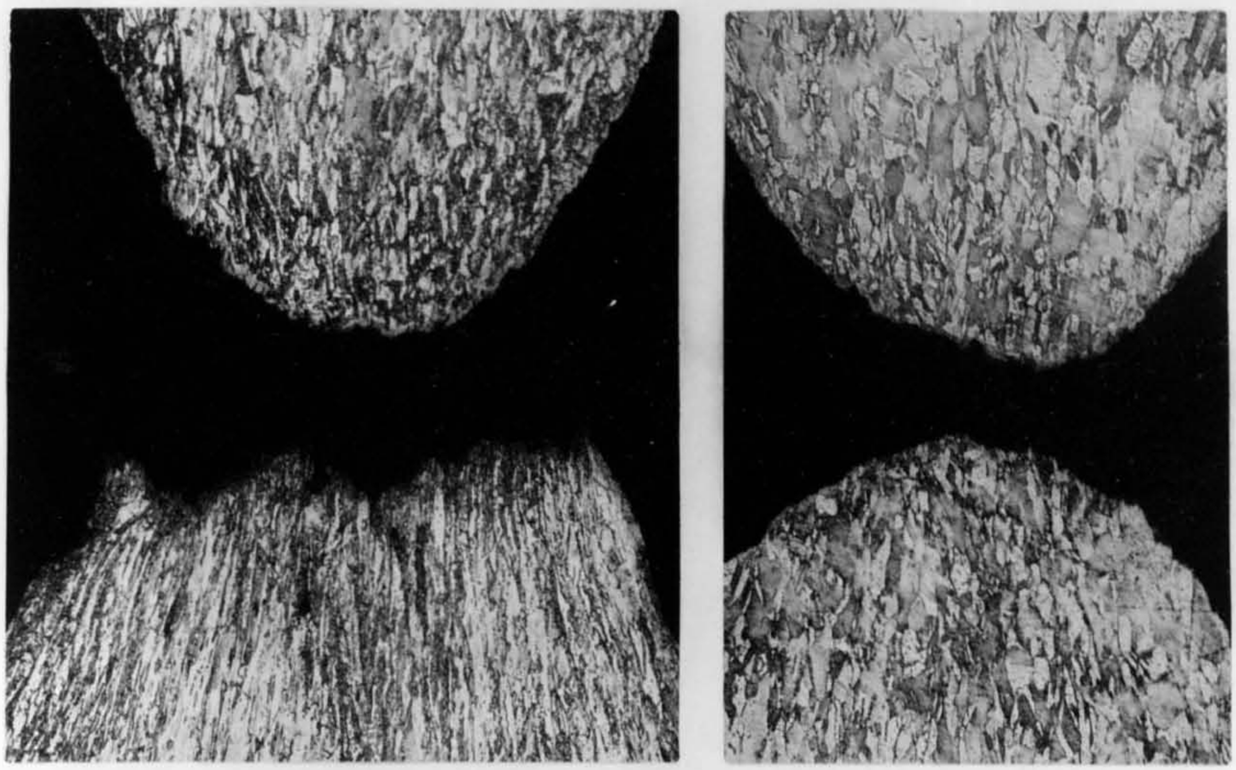
Original Magnification: 500X

Tested at 250 deg F and 33.0 ksi. Failed after 9.2 hours.

FIG. 14 FRACTURED SURFACE OF HIGH PURITY COPPER WIRE WITH 25 OZ PER TON SILVER ADDED



Longitudinal Section about 3 inches from Break



ETP COPPER

OF COPPER

Original Magnification: 500×

Fractured Surface

FIG. 15 MICROSTRUCTURE OF ETP AND OF COPPER SUBJECTED TO CREEP AT 250 DEG. F - BROKE AT 33 ksi AFTER 0.2 HR

APPENDIX I - COMPUTER PRINTOUTS

Explanation

The sheets numbered as sheet 1 and 2 of the computer printout are copies of the data input for the first four sets of creep data, at 73F, namely for tough pitch copper, tough pitch copper with 25 oz/ton of silver, tough pitch copper with 60 oz/ton of silver and OF copper. The first two lines at the top of page 1 represent program parameters, the next seven lines represent headings for the data output. Line 10 gives the Notebook number, 52731; the page, 4; the test temperature in degrees F, 73.0; the specimen diameter in inches, 0.0201; the nominal gage length in inches, 50.0; the number of stress levels for this data set, 2; the number of specimens tested at each stress level, 2; and the number of times data was taken, 9. Line 11 shows the two stress levels used in this data set in ksi, 10.0, 17.5. The left hand column below line 11 gives the times at which data was taken in hours (0.0, 1.0, 4.0, 25.4, 98.0, 262.0, 533.1, 843.7, 1007.0). The next two columns represent length measurements at those times for the two specimens at the 10.0 ksi stress level, the last two columns for the specimens at the 17.5 ksi stress level. The data output shown on page 3 of Appendix I and the "Stare" graphical output are self explanatory.

The creep curves have been fit to the following equation:

$$\ell n[\varepsilon(t,\sigma)] = \ell n[C_1(\sigma)] + C_2(\sigma)\ell nt + C_3(\sigma)[\ell nt]^2$$

$$+ C_4(\sigma)[\ell nt]^3 + C_5(\sigma)[\ell nt]^4$$

where:

ε = creep strain

σ = creep stress

t = time

C_1, C_2, C_3, C_4, C_5 are constants which are shown in the data output.

A typical data input for the stress relaxation data is shown on p. 90 of Appendix I.

The first 6 lines represent headings for the various data outputs. Line 8 gives the notebook No., page, specimen diameter, test temperature, the number of times data was taken, the number of stress levels and the number of specimens at each stress level. The first column below line 8 represents the various times at which data was taken, the next two columns represent resonant frequency measurements at various times for each of the two test specimens at stress level 1, the next two columns similarly apply to stress level No. 2. The last line gives the two initial stress levels used for the particular data set and the corresponding resonant frequency. The equations used to fit the stress-relaxation data are shown on the printout on page 91 of Appendix I.

①

```
4 1
2 4 1.0 0.01
CREEP OF ETP COPPER WIRE COLD WORKED 10 PERCENT
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =1 TEMPERATURE =73F
NONE
CREEP STRAIN
NONE
TIME,HOURS
ETP COPPER WIRE AT 73 DEG F
52731 4 73.0 0.0201 50.0 2 2 9
10.0 17.5
0.0 50.1077 50.0710 50.1190 50.1271
1.0 50.1114 50.0722 50.1213 50.1322
4.0 50.1132 50.0752 50.1256 50.1343
25.4 50.1153 50.0756 50.1301 50.1391
98.0 50.1171 50.0769 50.1349 50.1435
262.0 50.1201 50.0786 50.1395 50.1486
533.1 50.1223 50.0814 50.1448 50.1535
 843.7 50.1229 50.0831 50.1473 50.1552
 1007.0 50.1239 50.0831 50.1483 50.1558
2 4 1.0 0.01
CREEP OF ETP COPPER WIRE WITH 25 OZ PER TON OF SILVER
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =2 TEMPERATURE =73F
NONE
CREEP STRAIN
NONE
TIME,HOURS
TP COPPER WIRE WITH 25OZ PER TON AG AT 73 DEG F
2731 4 73.0 0.0201 50.0 2 2 9
0.0 20.7
 0.0 50.1077 50.1117 50.1448 50.1547
 1.0 50.1078 50.1119 50.1487 50.1572
 4.0 50.1107 50.1120 50.1492 50.1589
25.4 50.1109 50.1132 50.1524 50.1597
98.0 50.1114 50.1139 50.1540 50.1638
62.7 50.1128 50.1150 50.1540 50.1641
33.1 50.1132 50.1156 50.1564 50.1678
 843.7 50.1153 50.1166 50.1589 50.1666
1007.0 50.1165 50.1166 50.1592 50.1693
 4 1.0 0.01
REEP OF ETP COPPER WIRE WITH 60 OZ PER TON OF SILVER
RAPH SHOWS CREEP STRAIN VS TIME DATA SET =3 TEMPERATURE =73F
NE
EEP STRAIN
NE
ME HOURS
 P COPPER WIRE WITH 60 OZ PER TON AG AT 73 DEG F
 731 4 73.0 0.0201 50.0 2 2 9
 .0 21.4
 0.0 50.0986 50.0905 50.1372 50.1632
 1.0 50.0994 50.0905 50.1440 50.1680
 4.0 50.0990 50.0906 50.1453 50.1701
 5.4 50.0984 50.0914 50.1470 50.1710
 9.0 50.0962 50.0928 50.1495 50.1724
 2.7 [illegible] [illegible] 50.1521 50.1742
 3.1 [illegible] [illegible] 50.1564 50.1757
 943.7 50.0926 50.0936 50.1553 50.1757
 007.0 50.0926 50.0945 50.1562 50.1757
 4 1.0 0.01
```

JOB #1

3/23/72

RAN.

1000 HRS.

(2)

```
:REEP CF OF COPPER COLD WORKED 10 PER CENT
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =4 TEMPERATURE =73F
IONE
:REEP STRAIN
IONE
TIME HOURS
)F COPPER WIRE AT 73 DEG F
i2731 4 73.0 0.0201 50.0 2 2 9
.0.0 20.6
 0.0 50.1453 50.1140 50.1359 50.1296
.0 50.1460 50.1150 50.1412 50.1368
 4.0 50.1459 50.1161 50.1430 50.1383
25.4 50.1467 50.1172 50.1461 50.1397
98.0 50.1476 50.1185 50.1498 50.1430
162.7 50.1487 50.1193 50.1535 50.1455
i33.1 50.1510 50.1217 50.1557 50.1472
 843.7 50.1517 50.1217 50.1568 50.1495
1007.0 50.1529 50.1225 50.1576 50.1502
```

3

D A T A   S E T   N U M B E R   1

NOTEBOOK NUMBER 52731 PAGE 4
MATERIAL:ETP COPPER WIRE AT 73 DEG F
MATERIAL:
CREEP TEST
TEMPERATURE (IN DEGREES F): 73.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 50.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.4900E-04	0.4896E-04	0.05
4.0	0.9700E-04	0.9719E-04	0.19
25.4	0.1220E-03	0.1215E-03	0.40
98.0	0.1530E-03	0.1534E-03	0.24
262.0	0.2000E-03	0.2013E-03	0.65
533.1	0.2500E-03	0.2470E-03	1.19
843.7	0.2750E-03	0.2746E-03	0.59
1007.0	0.2830E-03	0.2829E-03	0.02

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.9924E 01
C(2) = 0.6634E 00
C(3) = -0.3489E 00
C(4) = 0.6485E-01
C(5) = -0.3928E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.1293E-05
STANDARD DEVIATION FOR ALL TIME = 0.1293E-05

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 17.50 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.7400E-04	0.7392E-04	0.11
4.0	0.1380E-03	0.1386E-03	0.44
25.4	0.2310E-03	0.2288E-03	0.95
98.0	0.3230E-03	0.3253E-03	0.70
262.0	0.4220E-03	0.4265E-03	1.08
533.1	0.5220E-03	0.5120E-03	1.91
843.7	0.5640E-03	0.5652E-03	0.21
1007.0	0.5800E-03	0.5834E-03	0.59

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = --0.9513E 01
C(2) = 0.6175E 00
C(3) = -0.1323E 00
C(4) = 0.2679E-01
C(5) = -0.1554E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.4239E-05
STANDARD DEVIATION FOR ALL TIME = 0.4239E-05

....

ONLY STARE OUTPUT CALLED FOR

D A T A S E T N U M B E R 2

NOTEBOOK NUMBER 52731 PAGE 4
MATERIAL:ETP COPPER WIRE WITH 25OZ PER TON AG
MATERIAL: AT 73 DEG F
CREEP TEST
TEMPERATURE (IN DEGREES F): 73.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 50.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.2999E-05	0.3020E-05	0.68
4.0	0.3300E-04	0.3214E-04	2.61
25.4	0.4700E-04	0.4978E-04	5.92
98.0	0.5900E-04	0.5669E-04	3.92
262.7	0.8400E-04	0.7835E-04	6.72
533.1	0.9400E-04	0.1057E-03	12.41
843.7	0.1250E-03	0.1249E-03	0.08
1007.0	0.1370E-03	0.1310E-03	4.35

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.1271E 02
C(2) = 0.2941E 01
C(3) = -0.1122E 01
C(4) = 0.1808E 00
C(5) = -0.9919E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.5211E-05
STANDARD DEVIATION FOR ALL TIME = 0.5211E-05

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 20.70 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.6400E-04	0.6409E-04	0.14
4.0	0.8600E-04	0.8541E-04	0.68
25.4	0.1260E-03	0.1292E-03	2.51
98.0	0.1830E-03	0.1724E-03	5.79
262.7	0.1940E-03	0.2117E-03	9.14
533.1	0.2670E-03	0.2464E-03	7.71
843.7	0.2600E-03	0.2734E-03	5.15
1007.0	0.2900E-03	0.2851E-03	1.71

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.9655E 01
C(2) = 0.1847E 00
C(3) = 0.2248E-01
C(4) = -0.5047E-02
C(5) = 0.3537E-03

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.1154E-04
STANDARD DEVIATION FOR ALL TIME = 0.1154E-04

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G

D A T A   S E T   N U M B E R   3

NOTEBOOK NUMBER 52731 PAGE 4
MATERIAL:ETP COPPER WIRE WITH 60 OZ PER TON A
MATERIAL:G AT 73 DEG F
CREEP TEST
TEMPERATURE (IN DEGREES F): 73.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 50.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.7997E-05	0.8053E-05	0.70
4.0	0.1300E-04	0.1264E-04	2.78
25.4	0.2700E-04	0.2893E-04	7.14
98.0	0.4500E-04	0.4160E-04	7.56
262.7	0.5000E-04	0.4970E-04	0.60
533.1	0.5500E-04	0.5936E-04	7.93
843.7	0.7300E-04	0.7148E-04	2.09
1007.0	0.8000E-04	0.7854E-04	1.82

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.1173E 02
C(2) = 0.3870E-01
C(3) = 0.2473E 00
C(4) = -0.6155E-01
C(5) = 0.4459E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.2207E-05
STANDARD DEVIATION FOR ALL TIME = 0.2207E-05

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 21.40 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.1160E-03	0.1160E-03	0.01
4.0	0.1500E-03	0.1501E-03	0.06
25.4	0.1760E-03	0.1758E-03	0.12
98.0	0.2150E-03	0.2151E-03	0.02
262.7	0.2590E-03	0.2602E-03	0.46
533.1	0.2970E-03	0.2939E-03	1.03
843.7	0.3060E-03	0.3097E-03	1.21
1007.0	0.3150E-03	0.3132E-03	0.57

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.9052E 01
C(2) = 0.3209E 00
C(3) = -0.1349E 00
C(4) = 0.2994E-01
C(5) = -0.2044E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.1869E-05
STANDARD DEVIATION FOR ALL TIME = 0.1869E-05

....

D A T A S E T N U M B E R 4

NOTEBOOK NUMBER 52731 PAGE 4
MATERIAL:OF COPPER WIRE AT 73 DEG F
MATERIAL:
CREEP TEST
TEMPERATURE (IN DEGREES F): 73.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 50.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.) CREEP STRAIN BEST FIT PERCENT ERROR

1.0	0.1700E-04	0.1697E-04	0.19
4.0	0.2700E-04	0.2718E-04	0.67
25.4	0.4600E-04	0.4553E-04	1.02
98.0	0.6800E-04	0.6718E-04	1.21
262.7	0.8700E-04	0.9323E-04	7.15
533.1	0.1340E-03	0.1220E-03	8.94
843.7	0.1410E-03	0.1480E-03	4.94
1007.0	0.1610E-03	0.1600E-03	0.60

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.1098E 02
C(2) = 0.3902E 00
C(3) = -0.4444E-01
C(4) = 0.6112E-02
C(5) = -0.1528E-03

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.5392E-05
STANDARD DEVIATION FOR ALL TIME = 0.5392E-05

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 20.60 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.1150E-03	0.1152E-03	0.20
4.0	0.1560E-03	0.1548E-03	0.77
25.4	0.2010E-03	0.2047E-03	1.83
98.0	0.2710E-03	0.2662E-03	1.77
262.7	0.3330E-03	0.3305E-03	0.76
533.1	0.3720E-03	0.3802E-03	2.20
843.7	0.4050E-03	0.4076E-03	0.39
1007.0	0.4210E-03	0.4158E-03	1.24

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

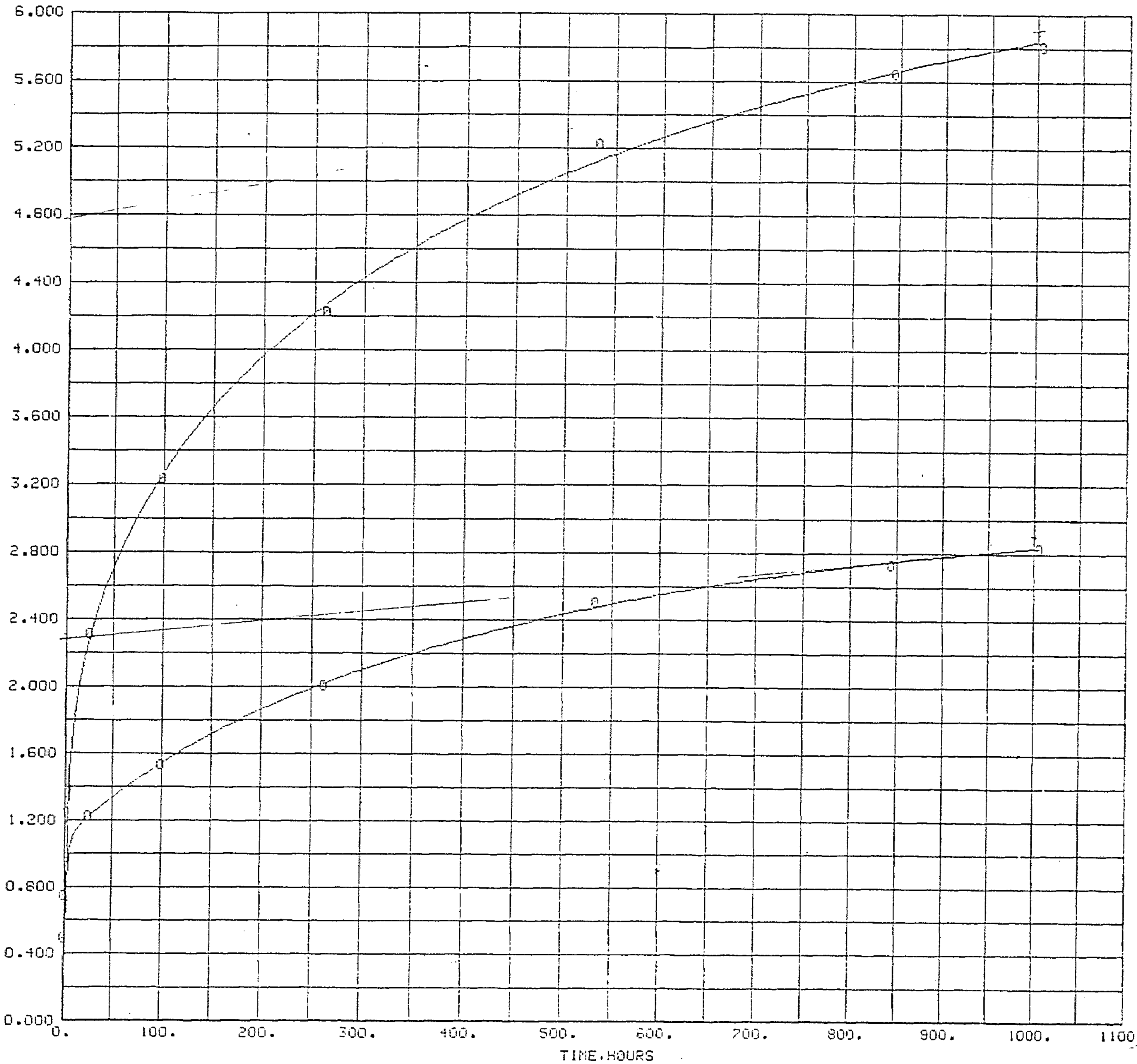
C(1) = -0.9159E 01
C(2) = 0.5005E 00
C(3) = -0.6835E-01
C(4) = 0.2014E-01
C(5) = -0.1412E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.4197E-05
STANDARD DEVIATION FOR ALL TIME = 0.4197E-05

....

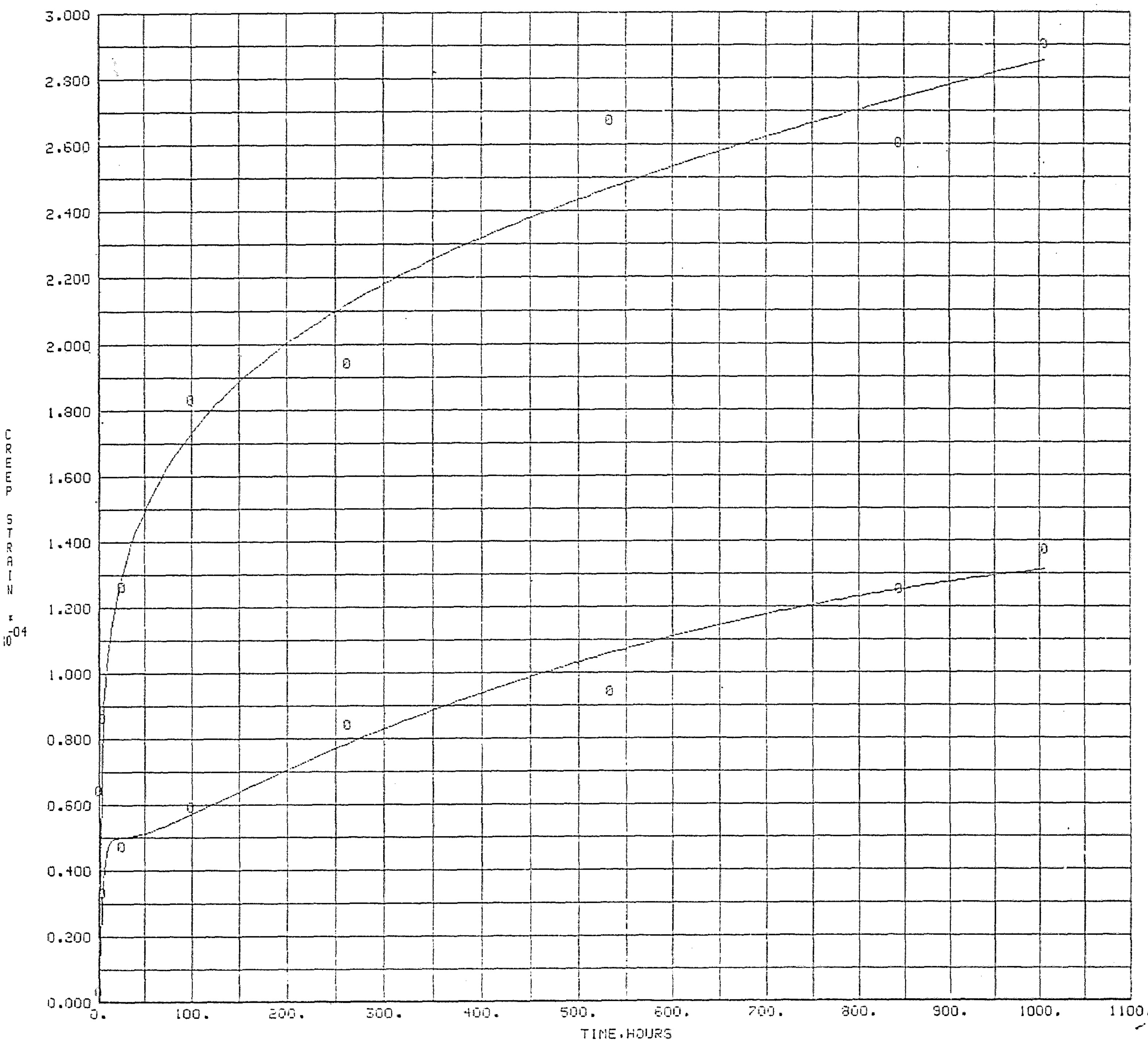
9

CREEP OF ETP COPPER WIRE COLD WORKED 10 PERCENT
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =1 TEMPERATURE =73F



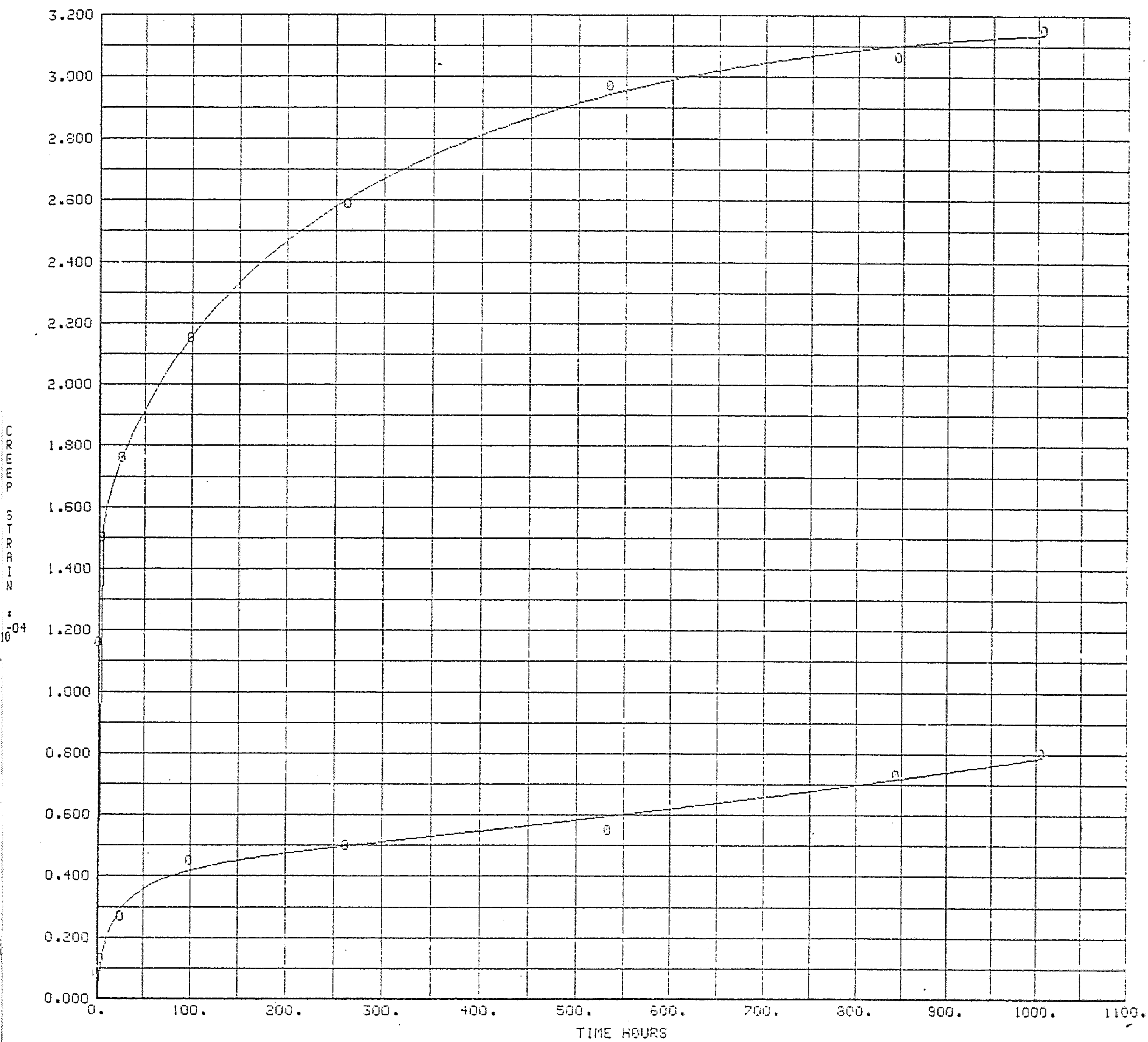
(10)

CREEP OF ETP COPPER WIRE WITH 25 OZ PER TON OF SILVER
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =2 TEMPERATURE =73F



(11)

CREEP OF ETP COPPER WIRE WITH 60 OZ PER TON OF SILVER
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =3 TEMPERATURE =73F



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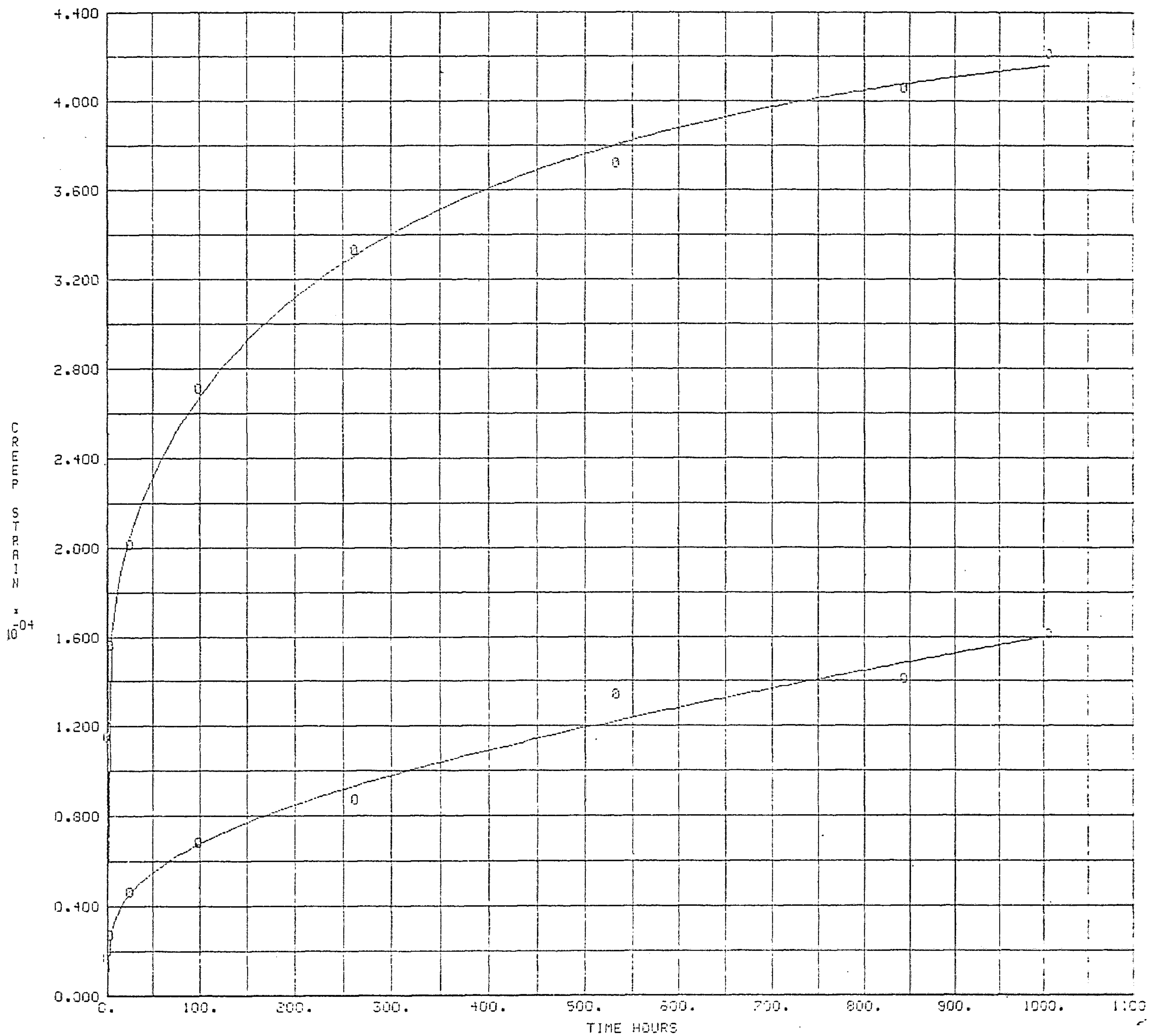
CREEP OF OF COPPER COLD WORKED 10 PER CENT

GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =4 TEMPERATURE =73F



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GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =1 TEMPERATURE =73F
NONE
CREEP STRAIN
NONE
TIME ,HOURS
OF COPPER WITH 25OZ PER TON AG AT 73 DEG F
52731 6 73.0 0.0201 50.0 2 2 9
10.0 22.1
0.0 50.0806 50.0705 50.1290 50.1504
1.0 50.0809 50.0720 50.1321 50.1526
4.0  50.0810 50.0730 50.1338 50.1553
  25.0 50.0810 50.0739 50.1349 50.1558
  98.0 50.0812 50.0744 50.1364 50.1579
 263.0 50.0820 50.0744 50.1383 50.1587
 533.0 50.0820 50.0744 50.1397 50.1598
  843.0 50.0820 50.0744 50.1397 50.1608
 1007.0 50.0828 50.0747 50.1397 50.1608
2 4 1.0 0.01
CREEP OF OF COPPER WIRE WITH 40 OZ PER TON OF SILVER AT 73F
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 2 TEMPERATURE = 73F
NONE
CREEP STRAIN
NONE
TIME ,HOURS
OF COPPER WIRE WITH 40 OZ PER TON OF SILVER AT 73F
52731 6 73.0 0.0201 50.0 2 2 9
10.0 18.7
0.0 50.0540 50.1052 50.0921 50.1460
1.0 50.0544 50.1056 50.0929 50.1475
    4.0 50.0548 50.1064 50.0934 50.1487
   30.0 50.0548 50.1064 50.0946 50.1497
   76.0 50.0548 50.1064 50.0951 50.1501
  244.3 50.0548 50.1070 50.0964 50.1517
  511.3 50.0548 50.1075 50.0988 50.1532
  846.9 50.0550 50.1072 50.0975 50.1539
 1230.1 50.0550 50.1076 50.0980 50.1522
2 4 1.0 0.01
CREEP OF OF COPPER WIRE WITH 60 OZ OF SILVER PER TON AT 73F
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 3 TEMPERATURE = 73F
NONE
CREEP STRAIN
NONE
TIME, HOURS
OF COPPER WIRE WITH 60 OZ PER TON OF SILVER AT 73 F
52731 6 73.0 0.0201 50.0 2 2 9
10.0 24.2
    0.0 50.0633 50.0927 50.1524 50.1283
    1.0 50.0634 50.0939 50.1529 50.1301
    4.0 50.0635 50.0946 50.1539 50.1310
   30.0 50.0635 50.0948 50.1546 50.1316
   76.0 50.0635 50.0955 50.1556 50.1323
  244.3 50.0635 50.0955 50.1565 50.1329
  511.3 50.0636 50.0955 50.1570 50.1331
  846.9 50.0645 50.0946 50.1570 50.1331
 1230.1 50.0650 50.0944 50.1570 50.1338
2 4 1.0 0.01
CREEP OF HIGH PURITY(99.999+)PERCENT COPPER WIRE WITH 25 OZ PER TON AG
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =4 TEMPERATURE = 73F
NONE
```

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#2

3/24/72

CREEP STRAIN
NONE
TIME, HOURS
HIGH PURITY(99.999+)COPPER WIRE WITH 25 OZ PER TON AG
52731 6 73.0 0.0201 50.0 2 2 9
10.0 21.6

0.0	50.1261	50.1311	50.1335	50.1857
1.0	50.1267	50.1323	50.1370	50.1918
4.0	50.1277	50.1334	50.1387	50.1926
25.0	50.1284	50.1336	50.1420	50.1954
98.0	50.1308	50.1345	50.1444	50.1967
263.0	50.1308	50.1353	50.1449	50.1994
533.0	50.1319	50.1361	50.1475	50.2011
846.9	50.1322	50.1372	50.1501	50.2031
1230.1	50.1332	50.1377	50.1508	50.2045

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D A T A   S E T   N U M B E R   1

NOTEBOOK NUMBER 52731 PAGE 6
MATERIAL:OF COPPER WIRE WITH 25OZ PER TON AG
MATERIAL:AT 73 DEG F
CREEP TEST
TEMPERATURE (IN DEGREES F): 73.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 50.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.1800E-04	0.1806E-04	0.32
4.0	0.2900E-04	0.2867E-04	1.16
25.0	0.3800E-04	0.3879E-04	2.07
98.0	0.4500E-04	0.4505E-04	0.11
263.0	0.5300E-04	0.5027E-04	5.15
533.0	0.5300E-04	0.5468E-04	3.18
843.0	0.5300E-04	0.5785E-04	9.16
1007.0	0.5400E-04	0.5914E-04	7.60

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.1092E 02
C(2) = 0.4517E 00
C(3) = -0.1025E 00
C(4) = 0.1308E-01
C(5) = -0.5959E-03

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.2699E-05
STANDARD DEVIATION FOR ALL TIME = 0.2699E-05

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 22.10 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.5300E-04	0.5313E-04	0.25
4.0	0.9700E-04	0.9599E-04	1.04
25.0	0.1130E-03	0.1161E-03	2.73
93.0	0.1490E-03	0.1436E-03	3.64
263.0	0.1760E-03	0.1787E-03	1.55
533.0	0.2010E-03	0.2032E-03	1.10
843.0	0.2110E-03	0.2104E-03	0.27
1007.0	0.2110E-03	0.2098E-03	0.56

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CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.9843E 01
C(2) = 0.7619E 00
C(3) = -0.3209E 00
C(4) = 0.6261E-01
C(5) = -0.4047E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.2601E-05
STANDARD DEVIATION FOR ALL TIME = 0.2601E-05

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ONLY STARE OUTPUT CALLED FOR

D A T A S E T N U M B E R 2

NOTEBOOK NUMBER 52731 PAGE 6
MATERIAL:OF COPPER WIRE WITH 40 OZ PER TON OF
MATERIAL: SILVER AT 73F
CREEP TEST
TEMPERATURE (IN DEGREES F): 73.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 50.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.8001E-05	0.8007E-05	0.08
4.0	0.2000E-04	0.1997E-04	0.18
30.0	0.2000E-04	0.1987E-04	0.66
76.0	0.2000E-04	0.2051E-04	2.54
244.3	0.2600E-04	0.2535E-04	2.52
511.3	0.3100E-04	0.3004E-04	3.12
846.9	0.3000E-04	0.3245E-04	8.14
1230.1	0.3400E-04	0.3272E-04	3.76

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CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.1174E 02
C(2) = 0.1279E 01
C(3) = -0.5794E 00
C(4) = 0.1037E 00
C(5) = -0.6137E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.1075E-05
STANDARD DEVIATION FOR ALL TIME = 0.1075E-05

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 18.70 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.2300E-04	0.2284E-04	0.67
4.0	0.4000E-04	0.4102E-04	2.54
30.0	0.6200E-04	0.5793E-04	6.56
76.0	0.7100E-04	0.7410E-04	4.37
244.3	0.1000E-03	0.1074E-03	7.41
511.3	0.1390E-03	0.1277E-03	8.14
846.9	0.1330E-03	0.1315E-03	1.10
1230.1	0.1210E-03	0.1248E-03	3.16

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.1069E 02
C(2) = 0.7355E 00
C(3) = -0.3103E 00
C(4) = 0.6735E-01
C(5) = -0.4714E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.5328E-05
STANDARD DEVIATION FOR ALL TIME = 0.5328E-05

....

D A T A   S E T   N U M B E R   3

NOTEBOOK NUMBER 52731 PAGE 6
MATERIAL:OF COPPER WIRE WITH 60 OZ PER TON OF
MATERIAL: SILVER AT 73 F
CREEP TEST
TEMPERATURE (IN DEGREES F): 73.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 50.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.1300E-04	0.1310E-04	0.78
4.0	0.2100E-04	0.2037E-04	3.00
30.0	0.2300E-04	0.2538E-04	10.38
76.0	0.3000E-04	0.2717E-04	9.44
244.3	0.3000E-04	0.2989E-04	0.37
511.3	0.3100E-04	0.3162E-04	2.00
846.9	0.3100E-04	0.3246E-04	4.71
1230.1	0.3400E-04	0.3270E-04	3.82

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.1124E 02
C(2) = 0.4846E 00
C(3) = -0.1499E 00
C(4) = 0.2355E-01
C(5) = -0.1337E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.1514E-05
STANDARD DEVIATION FOR ALL TIME = 0.1514E-05

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 24.20 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.2300E-04	0.2312E-04	0.52
4.0	0.4200E-04	0.4117E-04	1.97
30.0	0.5500E-04	0.5835E-04	6.10
76.0	0.7200E-04	0.6843E-04	4.95
244.3	0.8700E-04	0.8534E-04	1.91
511.3	0.9400E-04	0.9529E-04	1.37
846.9	0.9400E-04	0.9855E-04	4.84
1230.1	0.1010E-03	0.9749E-04	3.47

(17) 19

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.1067E 02
C(2) = 0.6433E 00
C(3) = -0.2155E 00
C(4) = 0.3990E-01
C(5) = -0.2580E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.2785E-05
STANDARD DEVIATION FOR ALL TIME = 0.2785E-05

....

D A T A S E T N U M B E R 4

NOTEBOOK NUMBER 52731 PAGE 6
MATERIAL:HIGH PURITY(99.999+)COPPER WIRE WITH
MATERIAL: 25 OZ PER TON AG
CREEP TEST
TEMPERATURE (IN DEGREES F): 73.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 50.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR

1.0	0.1800E-04	0.1820E-04	1.12
4.0	0.3900E-04	0.3728E-04	4.39
25.0	0.4800E-04	0.5355E-04	11.56
98.0	0.8100E-04	0.7077E-04	12.62
263.0	0.8900E-04	0.9227E-04	3.67
533.0	0.1030E-03	0.1119E-03	3.63
846.9	0.1220E-03	0.1245E-03	2.08
1230.1	0.1370E-03	0.1325E-03	3.25

20

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.1001E 02
C(2) = 0.8130E 00
C(3) = -0.2751E 00
C(4) = 0.4864E-01
C(5) = -0.2885E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.4881E-05
STANDARD DEVIATION FOR ALL TIME = 0.4881E-05

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 21.60 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.9600E-04	0.9575E-04	0.27
4.0	0.1210E-03	0.12[illegible]-03	1.01
25.0	0.1820E-03	[illegible]	1.97
98.0	0.2190E-03	[illegible]	1.09
263.0	0.2510E-03	[illegible]	1.96
533.0	0.2940E-03	[illegible]	0.64
846.9	0.3400E-03	0.32[illegible]2E-03	3.48
1230.1	0.3610E-03	0.3698E-03	2.44

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.9254E 01
C(2) = 0.1104E 00
C(3) = 0.7066E-01
C(4) = -0.1829E-01
C(5) = 0.1407E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.5766E-05
STANDARD DEVIATION FOR ALL TIME = 0.5766E-05

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NB C0489 13.123 03/24
XM274,HAL
GE NB 01

(18)

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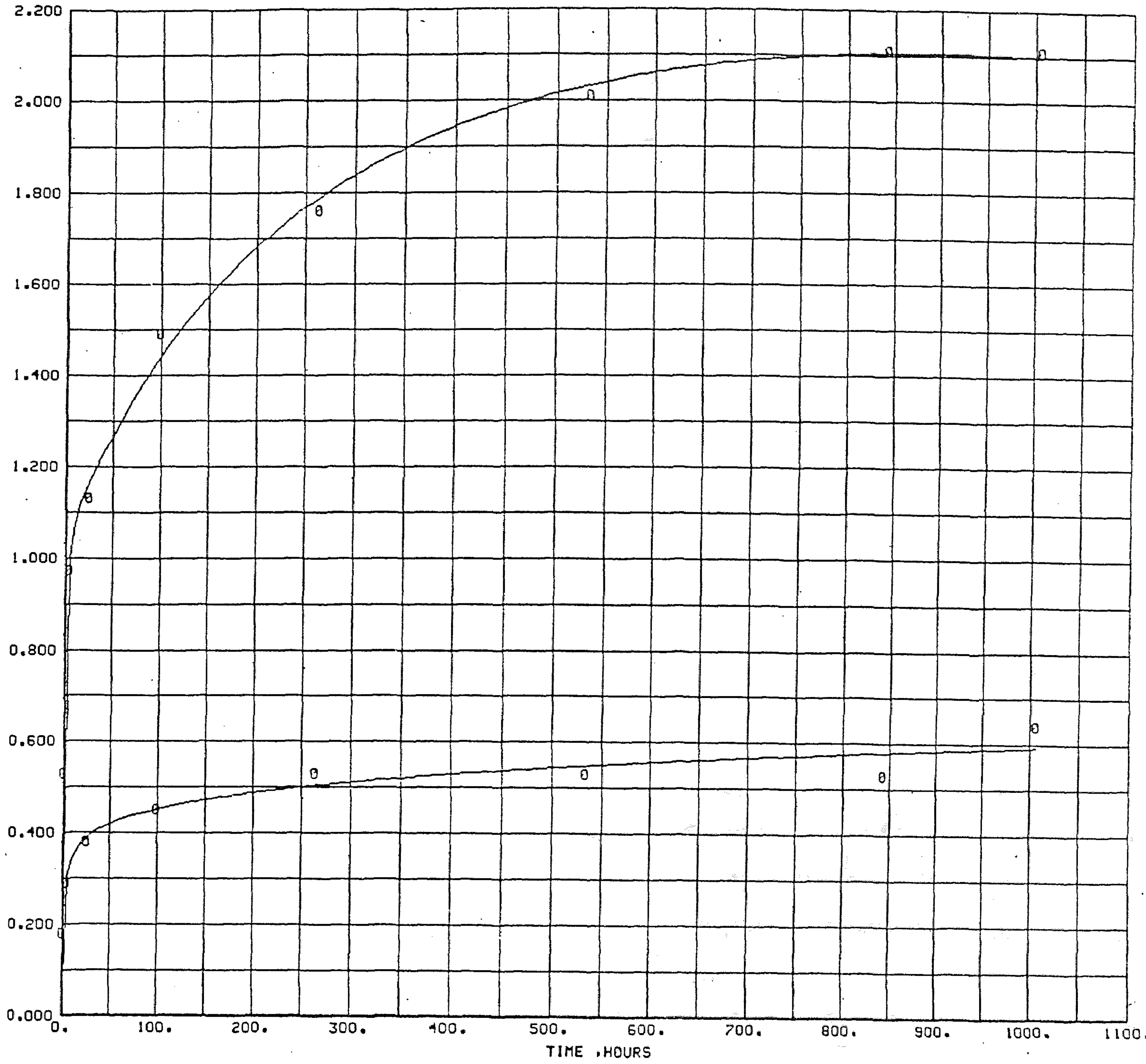
(21)

CREEP OF OF COPPER WIRE WITH 25 OZ AG PER TON AT 73 F
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =1 TEMPERATURE =73F



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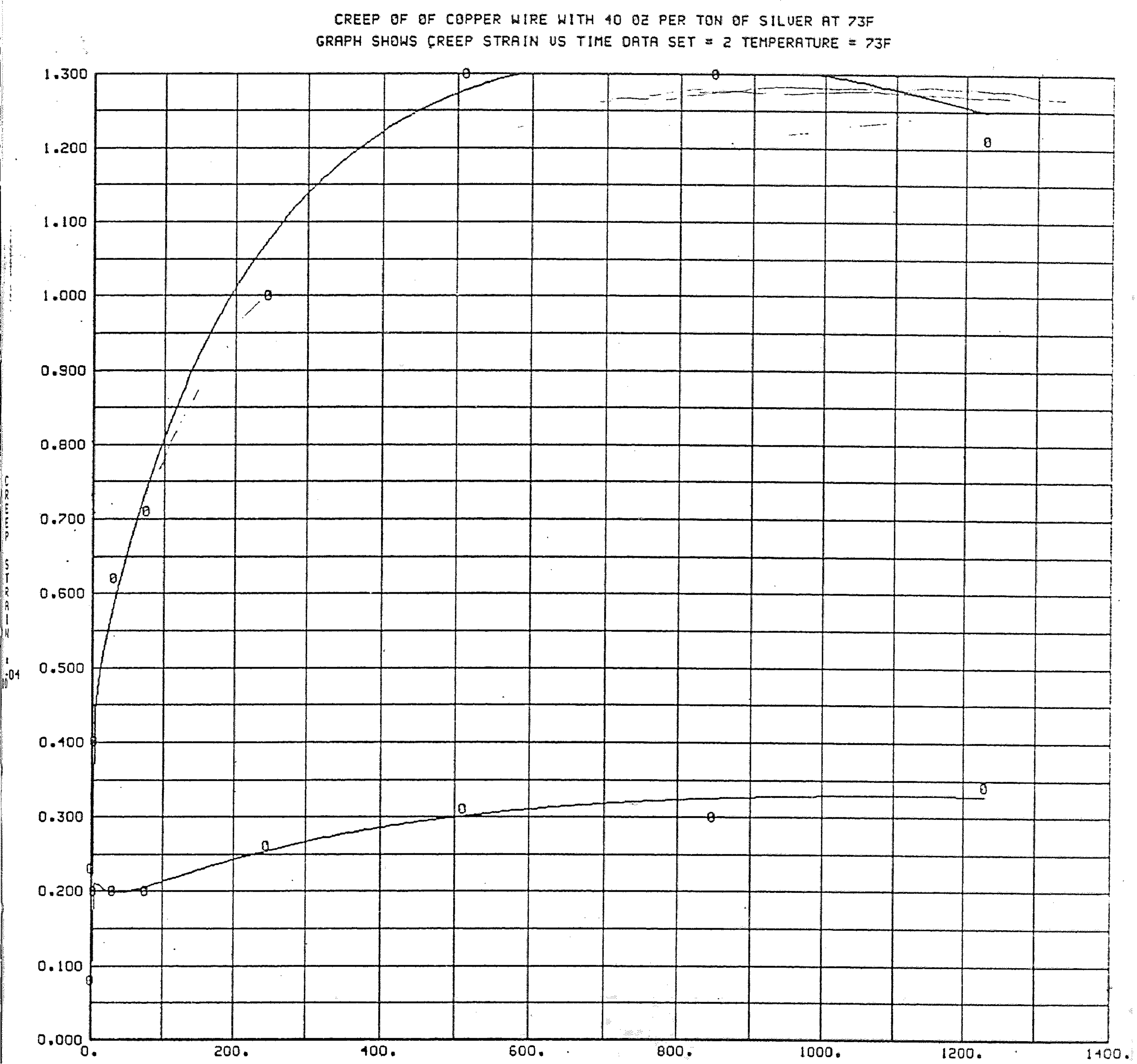
Chick Rate -



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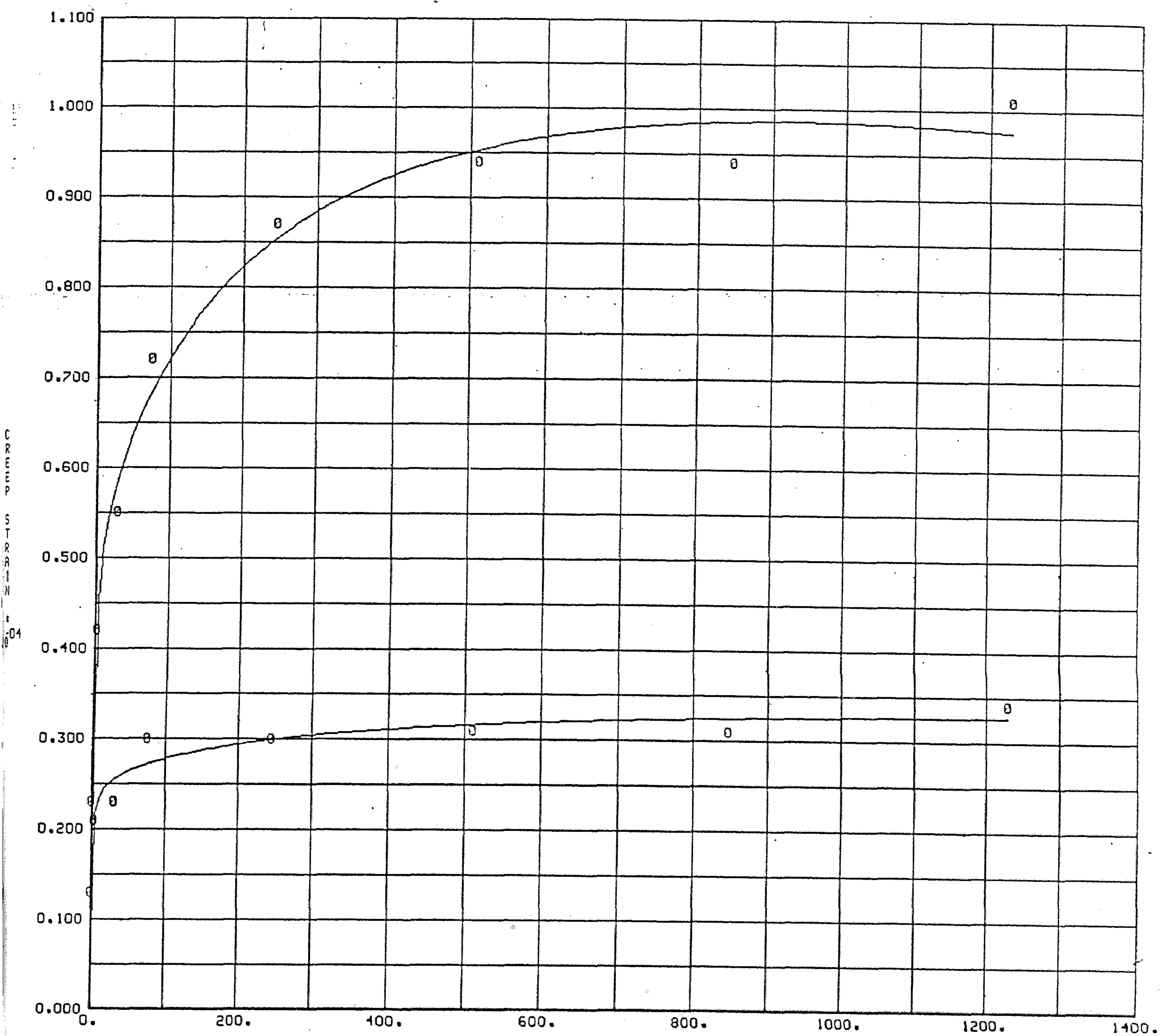
PAGE N0 03

22

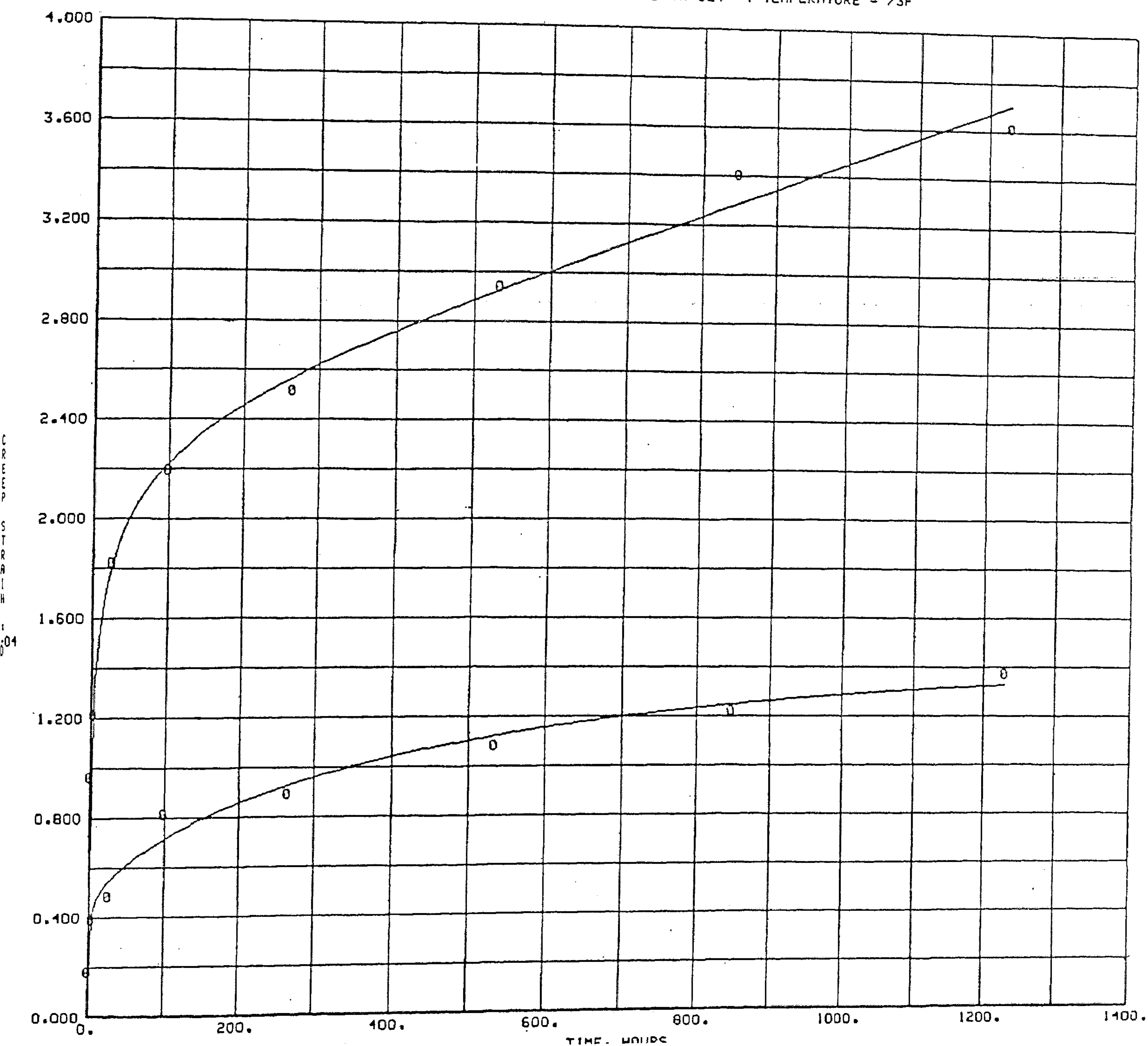
CREEP 0F 0F COPPER WIRE WITH 60 0Z 0F SILVER PER TON AT 73F
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 3 TEMPERATURE = 73F



NUMB C0489 13.123 03/24
60XM274.HAL
PAGE NO 04

(24)

CREEP OF HIGH PURITY(99.999+)PERCENT COPPER WIRE WITH 25 OZ PER TON AG
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =4 TEMPERATURE = 73F



p.25

Job #3

RAN 4/4/72

```
3 1
2 4 1.0 0.01
CREEP OF ETP COPPER WITH 25 OZ SILVER PER TON AT 250 F
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 1 TEMPERATURE = 250 DEG F
NONE
CREEP STRAIN
NONE
TIME ,HOURS
ETP COPPER WITH 25 OZ OF SILVER PER TON AT 250 DEG F
52731 10 250.0 0.0201 36.0 2 2 14
10.0 20.7
   0.0    36.0230 36.0260 36.0623 36.0556
   1.3    36.0266 36.0288 36.0717 36.0685
   4.0    36.0261 36.0306 36.0816 36.0750
  29.0    36.0337 36.0363 36.0972 36.0915
  49.0    36.0366 36.0382 36.1039 36.0979
 120.8    36.0406 36.0424 36.1162 36.1100
 222.3    36.0443 36.0466 36.1281 36.1224
 337.9    36.0482 36.0500 36.1377 36.1310
 385.5    36.0491 36.0514 36.1401 36.1358
 480.7    36.0500 36.0527 36.1448 36.1398
 625.1    36.0518 36.0552 36.1531 36.1462
  794.9 36.0541 36.0569 36.1581 36.1532
  962.5 36.0558 36.0595 36.1635 36.1585
 1200.7 36.0569 36.0602 36.1698 36.1648
2 4 1.0 0.01
CREEP OF ETP COPPER WITH 60 OZ SILVER PER TON AT 250 F
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =2 TEMPERATURE = 250 DEG F
NONE
CREEP STRAIN
NONE
TIME ,HOURS
ETP COPPER WITH 60 OZ OF SILVER PER TON AT 250 DEG F
52731 10 250.0 0.0201 36.0 2 2 14
10.0 21.4
   0.0 36.0250 36.0138 36.0621 36.0480
   1.3 36.0273 36.0197 36.0704 36.0587
   4.0 36.0286 36.0216 36.0746 36.0641
  29.0 36.0322 36.0263 36.0864 36.0744
  49.0 36.0340 36.0279 36.0902 36.0790
 120.8 36.0368 36.0311 36.0987 36.0877
 222.3 36.0400 36.0318 36.1061 36.0965
 337.9 36.0415 36.0355 36.1101 36.0993
 385.5 36.0423 36.0362 36.1116 36.1022
 480.7 36.0439 36.0371 36.1150 36.1042
 625.1 36.0439 36.0392 36.1185 36.1091
  794.9 36.0453 36.0409 36.1215 36.1109
  962.5 36.0480 36.0426 36.1241 36.1148
 1200.7 36.0492 36.0435 36.1274 36.1174
2 4 1.0 0.01
CREEP OF OFHC COPPER WIRE AT 250 DEG F
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =3 TEMPERATURE =250 DEG F
NONE
CREEP STRAIN
NONE
TIME ,HOURS
OFHC COPPER AT 250 DEG F
52731 11 250.0 0.0201 36.0 2 2 14
10.0 20.6
```

0.0	36.0181	36.0476	36.0614	36.0738
1.3	36.0267	36.0529	36.0782	36.0888
4.0	36.0276	36.0551	36.0868	36.0990
29.0	36.0370	36.0618	36.1115	36.1277
49.0	36.0398	36.0649	36.1206	36.1396
120.8	36.0445	36.0711	36.1456	36.1715
222.3	36.0516	36.0766	36.1726	36.2088
337.9	36.0562	36.0809	36.1981	36.2449
385.5	36.0584	36.0820	36.2089	36.2597
480.7	36.0614	36.0853	36.2267	36.2868
625.1	36.0653	36.0887	36.2546	36.3282
794.9	36.0677	36.0919	36.2733	36.3571
962.5	36.0696	36.0951	36.3010	36.3978
1200.7	36.0734	36.0970	36.3355	36.4510

(27)

D A T A   S E T   N U M B E R   1

NOTEBOOK NUMBER 52731 PAGE 10
MATERIAL:ETP COPPER WITH 25 OZ OF SILVER PER
MATERIAL:TON AT 250 DEG F
CREEP TEST
TEMPERATURE (IN DEGREES F):250.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 36.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.3	0.8889E-04	0.8868E-04	0.24
4.0	0.1347E-03	0.1356E-03	0.68
29.0	0.2917E-03	0.2901E-03	0.55
49.0	0.3583E-03	0.3521E-03	1.73
120.8	0.4722E-03	0.4842E-03	2.53
222.3	0.5819E-03	0.5923E-03	1.77
337.9	0.6833E-03	0.6749E-03	1.23
385.5	0.7153E-03	0.7023E-03	1.82
480.7	0.7458E-03	0.7494E-03	0.47
625.1	0.8056E-03	0.8074E-03	0.23
794.9	0.8611E-03	0.8622E-03	0.12
962.5	0.9208E-03	0.9067E-03	1.53
1200.7	0.9458E-03	0.9590E-03	1.39

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.9426E 01
C(2) = 0.3619E 00
C(3) = 0.1331E-01
C(4) = -0.2499E-02
C(5) = 0.5232E-04

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.8420E-05
STANDARD DEVIATION FOR ALL TIME = 0.8420E-05

28

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 20.70 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.3	0.3097E-03	0.3100E-03	0.07
4.0	0.5375E-03	0.5362E-03	0.24
29.0	0.9833E-03	0.9929E-03	0.98
49.0	0.1165E-02	0.1154E-02	1.00
120.8	0.1504E-02	0.1513E-02	0.56
222.3	0.1842E-02	0.1833E-02	0.50
337.9	0.2094E-02	0.2092E-02	0.13
385.5	0.2194E-02	0.2180E-02	0.67
480.7	0.2315E-02	0.2332E-02	0.74
625.1	0.2519E-02	0.2522E-02	0.09
794.9	0.2686E-02	0.2698E-02	0.45
962.5	0.2835E-02	0.2838E-02	0.13
1200.7	0.3010E-02	0.2996E-02	0.46

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.8251E 01
C(2) = 0.6954E 00
C(3) = -0.1610E 00
C(4) = 0.2671E-01
C(5) = -0.1543E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.9878E-05
STANDARD DEVIATION FOR ALL TIME = 0.9878E-05

....

ONLY STARE OUTPUT CALLED FOR

D A T A S E T N U M B E R 2

NOTEBOOK NUMBER 52731 PAGE 16
MATERIAL:ETP COPPER WITH 60 OZ OF SILVER PER
MATERIAL:TON AT 250 DEG F
CREEP TEST
TEMPERATURE (IN DEGREES F):250.0

SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 36.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.3	0.1139E-03	0.1139E-03	0.00
4.0	0.1583E-03	0.1583E-03	0.04
29.0	0.2736E-03	0.2758E-03	0.82
49.0	0.3208E-03	0.3172E-03	1.12
120.8	0.4042E-03	0.4017E-03	0.61
222.3	0.4583E-03	0.4710E-03	2.78
337.9	0.5306E-03	0.5264E-03	0.79
385.5	0.5514E-03	0.5454E-03	1.09
480.7	0.5861E-03	0.5792E-03	1.18
625.1	0.6153E-03	0.6230E-03	1.26
794.9	0.6583E-03	0.6672E-03	1.34
962.5	0.7194E-03	0.7054E-03	1.94
1200.7	0.7486E-03	0.7538E-03	0.69

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.9157E 01
C(2) = 0.2939E 00
C(3) = 0.4303E-02
C(4) = -0.2554E-02
C(5) = 0.2366E-03

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.7058E-05
STANDARD DEVIATION FOR ALL TIME = 0.7058E-05

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 21.40 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.3	0.2639E-03	0.2644E-03	0.20
4.0	0.3972E-03	0.3949E-03	0.57
29.0	0.7042E-03	0.7100E-03	0.83
49.0	0.8208E-03	0.8241E-03	0.40
120.8	0.1060E-02	0.1063E-02	0.32
222.3	0.1313E-02	0.1257E-02	4.23
337.9	0.1379E-02	0.1403E-02	1.73
385.5	0.1440E-02	0.1451E-02	0.72
480.7	0.1515E-02	0.1531E-02	1.06
625.1	0.1632E-02	0.1628E-02	0.24
794.9	0.1699E-02	0.1715E-02	0.98
962.5	0.1789E-02	0.1783E-02	0.34

1200.7	0.1871E-02	0.1857E-02	0.74

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

30

C(1) = -0.3347E 01
C(2) = 0.4302E 00
C(3) = -0.5763E-01
C(4) = 0.1021E-01
C(5) = -0.6860E-03

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.1883E-04
STANDARD DEVIATION FOR ALL TIME = 0.1883E-04

....

D A T A S E T N U M B E R 3

NOTEBOOK NUMBER 52731 PAGE 11
MATERIAL:OFHC COPPER AT 250 DEG F
MATERIAL:
CREEP TEST
TEMPERATURE (IN DEGREES F):250.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 36.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.3	0.1931E-03	0.1921E-03	0.48
4.0	0.2361E-03	0.2395E-03	1.44
29.0	0.4597E-03	0.4485E-03	2.43
49.0	0.5417E-03	0.5357E-03	1.10
120.8	0.6931E-03	0.7211E-03	4.04
222.3	0.8681E-03	0.8744E-03	0.73
337.9	0.9917E-03	0.9953E-03	0.36
385.5	0.1038E-02	0.1036E-02	0.11

625.1	0.1226E-02	0.1202E-02	1.95
794.9	0.1304E-02	0.1296E-02	0.64
962.5	0.1375E-02	0.1376E-02	0.10
1200.7	0.1454E-02	0.1478E-02	1.64

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

37

C(1) = -0.8580E 01
C(2) = 0.6245E-01
C(3) = 0.1019E 00
C(4) = -0.1581E-01
C(5) = 0.8437E-03

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.1382E-04
STANDARD DEVIATION FOR ALL TIME = 0.1382E-04

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 20.60 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.3	0.4417E-03	0.4408E-03	0.20
4.0	0.7028E-03	0.7071E-03	0.62
29.0	0.1444E-02	0.1423E-02	1.46
49.0	0.1736E-02	0.1740E-02	0.22
120.8	0.2526E-02	0.2560E-02	1.34
222.3	0.3419E-02	0.3441E-02	0.63
337.9	0.4275E-02	0.4288E-02	0.31
385.5	0.4631E-02	0.4609E-02	0.47
480.7	0.5254E-02	0.5216E-02	0.73
625.1	0.6217E-02	0.6071E-02	2.35
794.9	0.6878E-02	0.7004E-02	1.84
962.5	0.7828E-02	0.7869E-02	0.53
1200.7	0.9046E-02	0.9027E-02	0.21

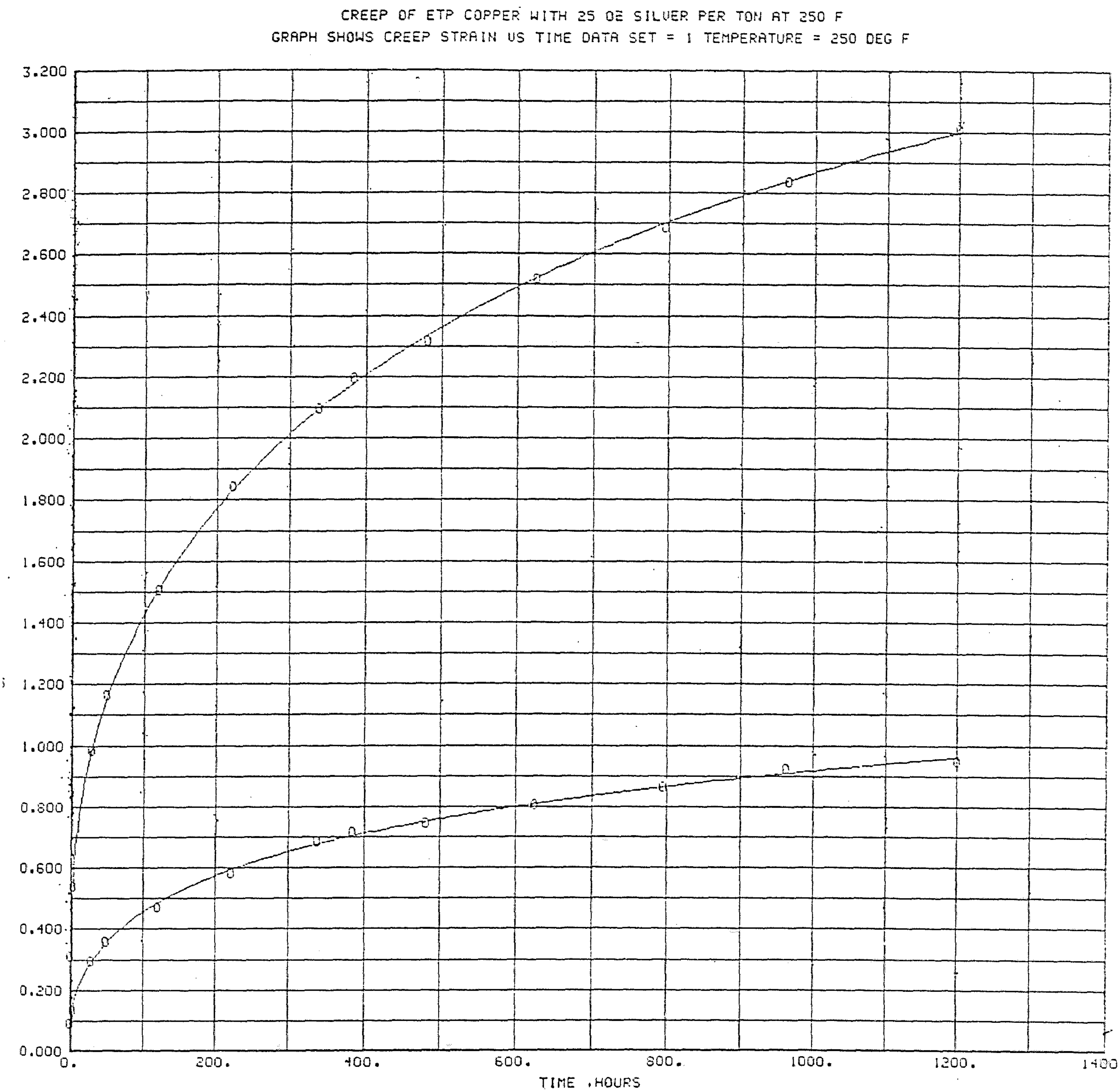
CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

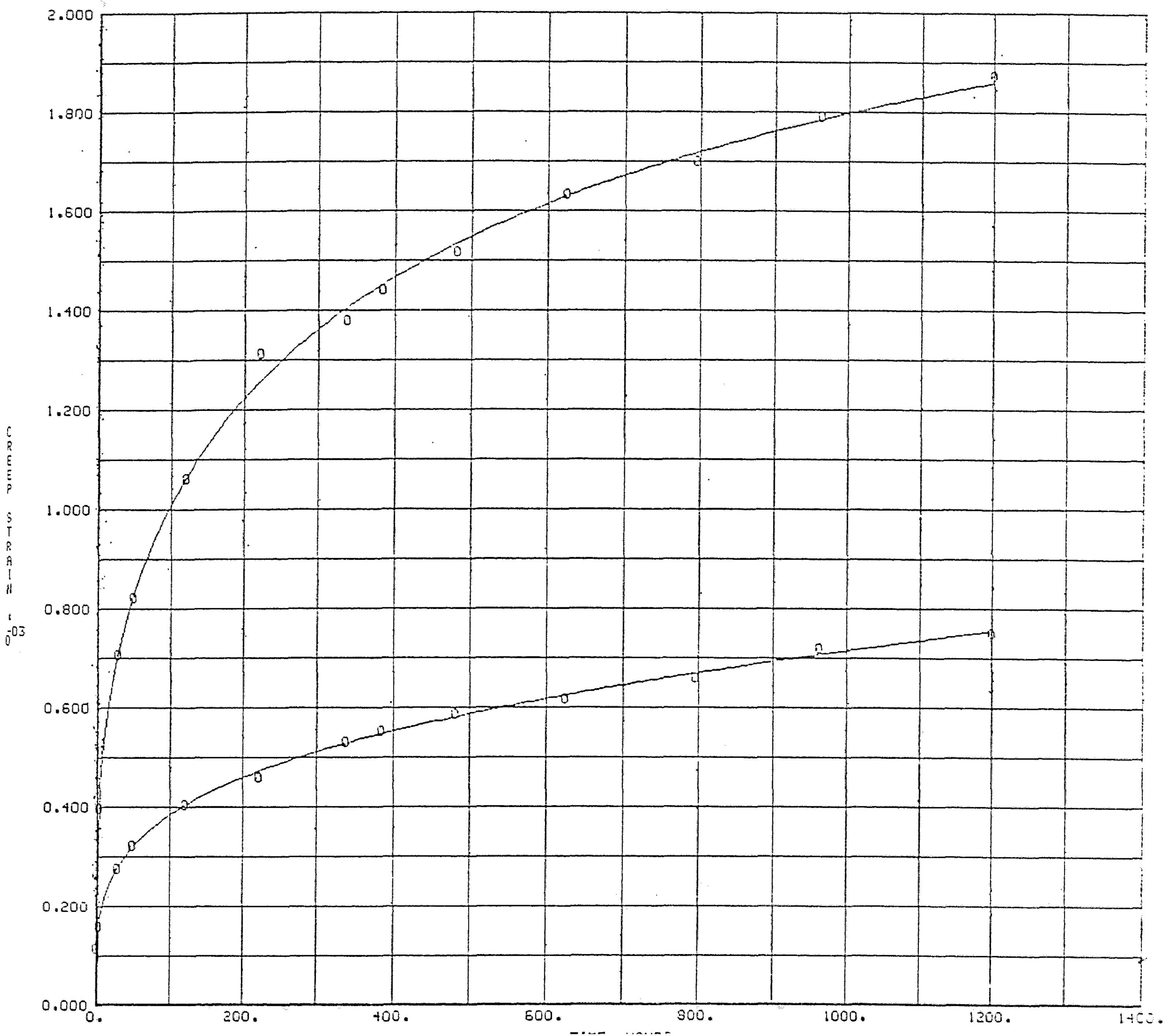
C(1) = -0.7860E 01
C(2) = 0.5291E 00
C(3) = -0.8704E-01
C(4) = 0.1589E-01
C(5) = -0.7463E-03

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.5788E-04
STANDARD DEVIATION FOR ALL TIME = 0.5788E-04

....


CREEP OF ETP COPPER WITH 25 OZ SILVER PER TON AT 250 F
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 1 TEMPERATURE = 250 DEG F
3.200
3.000
2.800
2.600
2.400
2.200
2.000
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
0.
200.
400.
600.
800.
1000.
1200.
1400.
TIME ,HOURS

CREEP OF ETP COPPER WITH 60 OZ SILVER PER TON AT 250 F
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =2 TEMPERATURE = 250 DEG F



NUMB C0068 15.014 04/04
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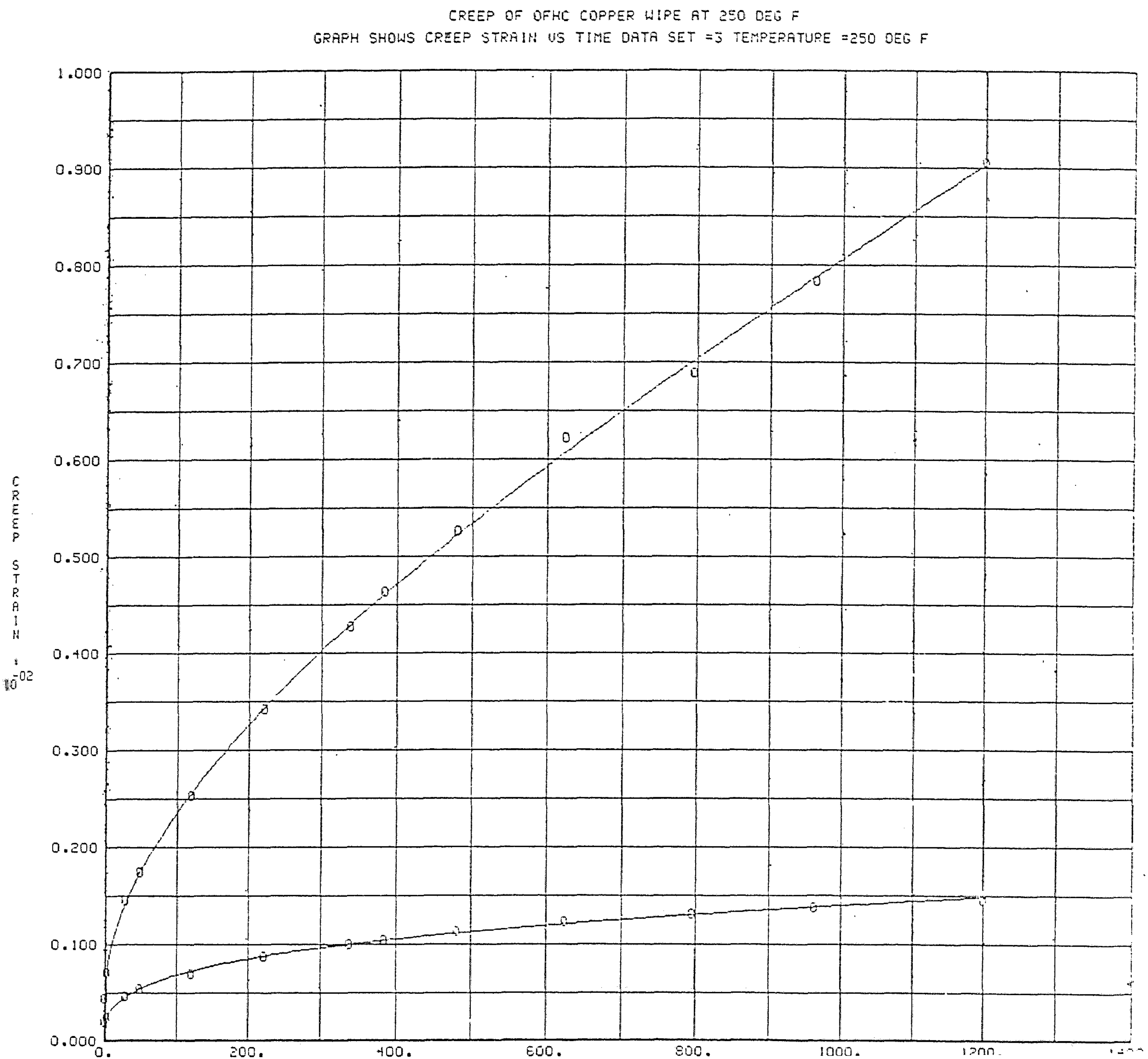
(34)



~~36~~ 35

Job A 4
1200 HR RUN
3/24/72

```
4 1
2 4 1.0 0.01
CREEP OF OFHC COPPER WIRE WITH 25 OZ PER TON OF SILVER
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =1 TEMPERATURE =250 DEG F
NONE
CREEP STRAIN
NONE
TIME,HOURS
OFHC COPPER WITH 25 OZ PER TON OF SILVER
52731 11 250.0 0.0201 36.0 2 2 14
10.0 22.1
    0.0 36.0136 36.0126 36.0600 36.0651
    1.3 36.0171 36.0145 36.0724 36.0778
    4.0 36.0180 36.0152 36.0769 36.0834
   29.0 36.0228 36.0193 36.0923 36.0974
   49.0 36.0248 36.0203 36.0980 36.1029
  120.8 36.0276 36.0227 36.1103 36.1144
  222.3 36.0310 36.0251 36.1226 36.1259
  337.9 36.0333 36.0283 36.1329 36.1358
  385.5 36.0340 36.0289 36.1357 36.1385
  480.7 36.0361 36.0295 36.1413 36.1432
  625.1 36.0377 36.0320 36.1482 36.1502
  794.9 36.0395 36.0334 36.1549 36.1557
  962.5 36.0412 36.0348 36.1601 36.1608
 1200.7 36.0420 36.0350 36.1675 36.1674
2 4 1.0 0.01
CREEP OF OFHC COPPER WIRE WITH 40 OZ PER TON OF SILVER
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =2 TEMPERATURE = 250 DEG F
NONE
CREEP STRAIN
NONE
TIME,HOURS
OFHC COPPER WITH 40 OZ PER TON OF SILVER
52731 11 250.0 0.0201 36.0 2 2 14
10.0 18.7
    0.0 36.0304 36.0215 36.0547 36.0466
    1.3 36.0316 36.0220 36.0588 36.0520
    4.0 36.0351 36.0221 36.0636 36.0547
   29.0 36.0358 36.0239 36.0701 36.0609
   49.0 36.0365 36.0250 36.0717 36.0630
  120.8 36.0395 36.0274 36.0767 36.0683
  222.3 36.0403 36.0291 36.0816 36.0743
  338.1 36.0421 36.0303 36.0853 36.0772
  386.3 36.0432 36.0310 36.0856 36.0779
  480.0 36.0434 36.0327 36.0880 36.0807
  625.0 36.0447 36.0327 36.0910 36.0833
  795.0 36.0467 36.0340 36.0919 36.0856
  962.0 36.0470 36.0341 36.0943 36.0879
 1200.7 36.0482 36.0350 36.0966 36.0898
2 4 1.0 0.01
CREEP OF ETP COPPER WIRE COLD WORKED 10 PERCENT
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 3 TEMPERATURE = 250 DEG F
NONE
CREEP STRAIN
NONE
TIME,HOURS
ETP COPPER COLD WORKED 10 PERCENT
52731 11 250.0 0.0201 36.0 2 2 12
10.0 17.5
```

```
   0.0 36.0775 36.0856 36.0854 36.0580
   1.0 36.0819 36.0901 36.0973 36.0693
   4.0 36.0912 36.0929 36.1065 36.0783
  29.6 36.0952 36.1015 36.1338 36.1032
  52.7 36.0998 36.1065 36.1500 36.1193
  97.8 36.1068 36.1124 36.1708 36.1408
 192.8 36.1156 36.1227 36.2089 36.1803
 337.4 36.1278 36.1338 36.2583 36.2294
 439.2 36.1330 36.1416 36.2916 36.2613
 507.3 36.1376 36.1435 36.3106 36.2817
 675.3 36.1447 36.1514 36.3601 36.3301
 912.7 36.1550 36.1595 36.4233 36.3925
2 4 1.0 0.01
CREEP OF OFHC COPPER WIRE WITH 60 OZ PER TON OF SILVER
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =4 TEMPERATURE = 250 DEG F
NONE
CREEP STRAIN
NONE
TIME ,HOURS
OFHC COPPER WIRE WITH 60 OZ PER TON OF SILVER
52731 11 250.0 0.0201 36.0 2 2 12
10.0 24.2
   0.0 36.0501 36.0534 36.1058 36.0931
   1.0 36.0502 36.0536 36.1116 36.0959
   4.0 36.0502 36.0540 36.1140 36.0989
  29.6 36.0526 36.0561 36.1193 36.1056
  52.7 36.0538 36.0565 36.1211 36.1089
  97.8 36.0542 36.0598 36.1242 36.1127
 192.8 36.0556 36.0598 36.1310 36.1162
 337.4 36.0568 36.0600 36.1324 36.1227
 439.2 36.0581 36.0620 36.1378 36.1231
 507.3 36.0581 36.0620 36.1378 36.1246
 675.3 36.0584 36.0627 36.1402 36.1267
 912.7 36.0594 36.0627 36.1418 36.1284
```

SNUMB = C0673, ACTIVITY # = 01, REPORT CODE = 06, RECORD COUNT = 00396

37

D A T A   S E T   N U M B E R   1

NOTEBOOK NUMBER 52731 PAGE 11
MATERIAL:OFHC COPPER WITH 25 OZ PER TON OF SI
MATERIAL:LVER
CREEP TEST
TEMPERATURE (IN DEGREES F):250.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 36.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.3	0.7500E-04	0.7441E-04	0.78
4.0	0.9723E-04	0.9953E-04	2.37
29.0	0.2208E-03	0.2122E-03	3.92
49.0	0.2625E-03	0.2583E-03	1.60
120.8	0.3347E-03	0.3529E-03	5.43
222.3	0.4153E-03	0.4283E-03	3.14
337.9	0.4917E-03	0.4870E-03	0.94
385.5	0.5097E-03	0.5071E-03	0.52
480.7	0.5472E-03	0.5427E-03	0.83
625.1	0.6042E-03	0.5893E-03	2.46
794.9	0.6486E-03	0.6370E-03	1.79
962.5	0.6917E-03	0.6795E-03	1.77
1200.7	0.7056E-03	0.7347E-03	4.13

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.9538E 01
C(2) = 0.8843E-01
C(3) = 0.1358E 00
C(4) = -0.2476E-01
C(5) = 0.1461E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.1241E-04
STANDARD DEVIATION FOR ALL TIME = 0.1241E-04

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 22.10 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.3	0.3486E-03	0.3481E-03	0.15
4.0	0.4889E-03	0.4911E-03	0.45
29.0	0.8972E-03	0.8892E-03	0.89
49.0	0.1053E-02	0.1049E-02	0.33
120.8	0.1383E-02	0.1407E-02	1.74
222.3	0.1714E-02	0.1721E-02	0.44
337.9	0.1994E-02	0.1975E-02	1.00
385.5	0.2071E-02	0.2061E-02	0.50
480.7	0.2214E-02	0.2211E-02	0.12
625.1	0.2407E-02	0.2401E-02	0.25
794.9	0.2576E-02	0.2583E-02	0.26
962.5	0.2719E-02	0.2733E-02	0.50
1200.7	0.2914E-02	0.2910E-02	0.13

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.8049E 01
C(2) = 0.3351E 00
C(3) = -0.2598E-01
C(4) = 0.6609E-02
C(5) = -0.4810E-03

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.1075E-04
STANDARD DEVIATION FOR ALL TIME = 0.1075E-04

....

D A T A S E T N U M B E R 2

NOTEBOOK NUMBER 52731 PAGE 11
MATERIAL:OFHC COPPER WITH 40 OZ PER TON OF SI
MATERIAL:LVER
CREEP TEST
TEMPERATURE (IN DEGREES F):250.0
SPECIMEN DIAMETER (IN INCHES): 0.0201

NOMINAL GAUGE LENGTH (INCHES): 36.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.3	0.2361E-04	0.2393E-04	1.35
4.0	0.7361E-04	0.7065E-04	4.02
29.0	0.1083E-03	0.1183E-03	9.20
49.0	0.1333E-03	0.1343E-03	0.70
120.8	0.2083E-03	0.1843E-03	11.55
222.3	0.2431E-03	0.2418E-03	0.51
338.1	0.2847E-03	0.2930E-03	2.90
386.3	0.3097E-03	0.3106E-03	0.27
480.0	0.3361E-03	0.3395E-03	1.00
625.0	0.3542E-03	0.3727E-03	5.24
795.0	0.4000E-03	0.3978E-03	0.55
962.0	0.4056E-03	0.4114E-03	1.45
1200.7	0.4347E-03	0.4174E-03	3.99

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.1109E 02
C(2) = 0.1884E 01
C(3) = -0.7290E 00
C(4) = 0.1304E 00
C(5) = -0.7862E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.1058E-04
STANDARD DEVIATION FOR ALL TIME = 0.1058E-04

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 18.70 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.3	0.1320E-03	0.1320E-03	0.07
4.0	0.2361E-03	0.2357E-03	0.16
29.0	0.4125E-03	0.4100E-03	0.60
49.0	0.4639E-03	0.4701E-03	1.34
120.8	0.6069E-03	0.6102E-03	0.54
222.3	0.7583E-03	0.7389E-03	2.56
338.1	0.8500E-03	0.8435E-03	0.76
386.3	0.8639E-03	0.8789E-03	1.74
480.0	0.9361E-03	0.9380E-03	0.21
625.0	0.1014E-02	0.1011E-02	0.33
795.0	0.1058E-02	0.1075E-02	1.56
962.0	0.1124E-02	0.1123E-02	0.09
1200.7	0.1182E-02	0.1172E-02	0.87

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.9130E 01
C(2) = 0.8115E 00
C(3) = -0.2323E 00
C(4) = 0.4038E-01
C(5) = -0.2410E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.9179E-05
STANDARD DEVIATION FOR ALL TIME = 0.9179E-05

....

D A T A S E T N U M B E R 3

NOTEBOOK NUMBER 52731 PAGE 11
MATERIAL:ETP COPPER COLD WORKED 10 PERCENT
MATERIAL:
CREEP TEST
TEMPERATURE (IN DEGREES F):250.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 36.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.1236E-03	0.1240E-03	0.29
4.0	0.2917E-03	0.2883E-03	1.16
29.6	0.4667E-03	0.4867E-03	4.29
52.7	0.6000E-03	0.5890E-03	1.83
97.8	0.7792E-03	0.7572E-03	2.82
192.8	0.1044E-02	0.1043E-02	0.15
337.4	0.1368E-02	0.1374E-02	0.43
439.2	0.1549E-02	0.1556E-02	0.49
507.3	0.1639E-02	0.1660E-02	1.29
675.3	0.1847E-02	0.1867E-02	1.05

912.7	0.2103E-02	0.2067E-02	1.69

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.8995E 01
C(2) = 0.9905E 00
C(3) = -0.3680E 00
C(4) = 0.7325E-01
C(5) = -0.4650E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.1706E-04
STANDARD DEVIATION FOR ALL TIME = 0.1706E-04

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 17.50 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.3222E-03	0.3223E-03	0.02
4.0	0.5750E-03	0.5743E-03	0.13
29.6	0.1300E-02	0.1314E-02	1.11
52.7	0.1749E-02	0.1719E-02	1.67
97.8	0.2336E-02	0.2349E-02	0.55
192.8	0.3414E-02	0.3419E-02	0.16
337.4	0.4782E-02	0.4794E-02	0.26
439.2	0.5688E-02	0.5675E-02	0.22
507.3	0.6235E-02	0.6239E-02	0.07
675.3	0.7594E-02	0.7571E-02	0.31
912.7	0.9339E-02	0.9354E-02	0.17

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.8040E 01
C(2) = 0.4485E 00
C(3) = -0.3345E-01
C(4) = 0.7997E-02
C(5) = -0.3092E-03

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.1469E-04
STANDARD DEVIATION FOR ALL TIME = 0.1469E-04

....

D A T A   S E T   N U M B E R   4

NOTEBOOK NUMBER 52731 PAGE 11
MATERIAL:OFHC COPPER WIRE WITH 60 OZ PER TON
MATERIAL:OF SILVER
CREEP TEST
TEMPERATURE (IN DEGREES F):250.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 36.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.4166E-05	0.4148E-05	0.42
4.0	0.9722E-05	0.9883E-05	1.65
29.6	0.7222E-04	0.6773E-04	6.22
52.7	0.9445E-04	0.1012E-03	7.20
97.8	0.1458E-03	0.1388E-03	4.82
192.8	0.1653E-03	0.1745E-03	5.59
337.4	0.1847E-03	0.1998E-03	8.17
439.2	0.2306E-03	0.2126E-03	7.79
507.3	0.2306E-03	0.2206E-03	4.33
675.3	0.2444E-03	0.2401E-03	1.80
912.7	0.2583E-03	0.2695E-03	4.33

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.1239E 02
C(2) = 0.1113E 00
C(3) = 0.5179E 00
C(4) = -0.1160E 00
C(5) = 0.7450E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.9515E-05
STANDARD DEVIATION FOR ALL TIME = 0.9515E-05

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 24.20 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR

44 43

1.0	0.1194E-03	0.1194E-03	0.06
4.0	0.1944E-03	0.1949E-03	0.23
29.6	0.3611E-03	0.3584E-03	0.75
52.7	0.4319E-03	0.4327E-03	0.18
97.8	0.5278E-03	0.5324E-03	0.87
192.8	0.6708E-03	0.6664E-03	0.66
337.4	0.7806E-03	0.7909E-03	1.33
439.2	0.8611E-03	0.8504E-03	1.24
507.3	0.8819E-03	0.8821E-03	0.02
675.3	0.9444E-03	0.9413E-03	0.33
912.7	0.9903E-03	0.9946E-03	0.44

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.9033E 01
C(2) = 0.4264E 00
C(3) = -0.7447E-01
C(4) = 0.1771E-01
C(5) = -0.1360E-02

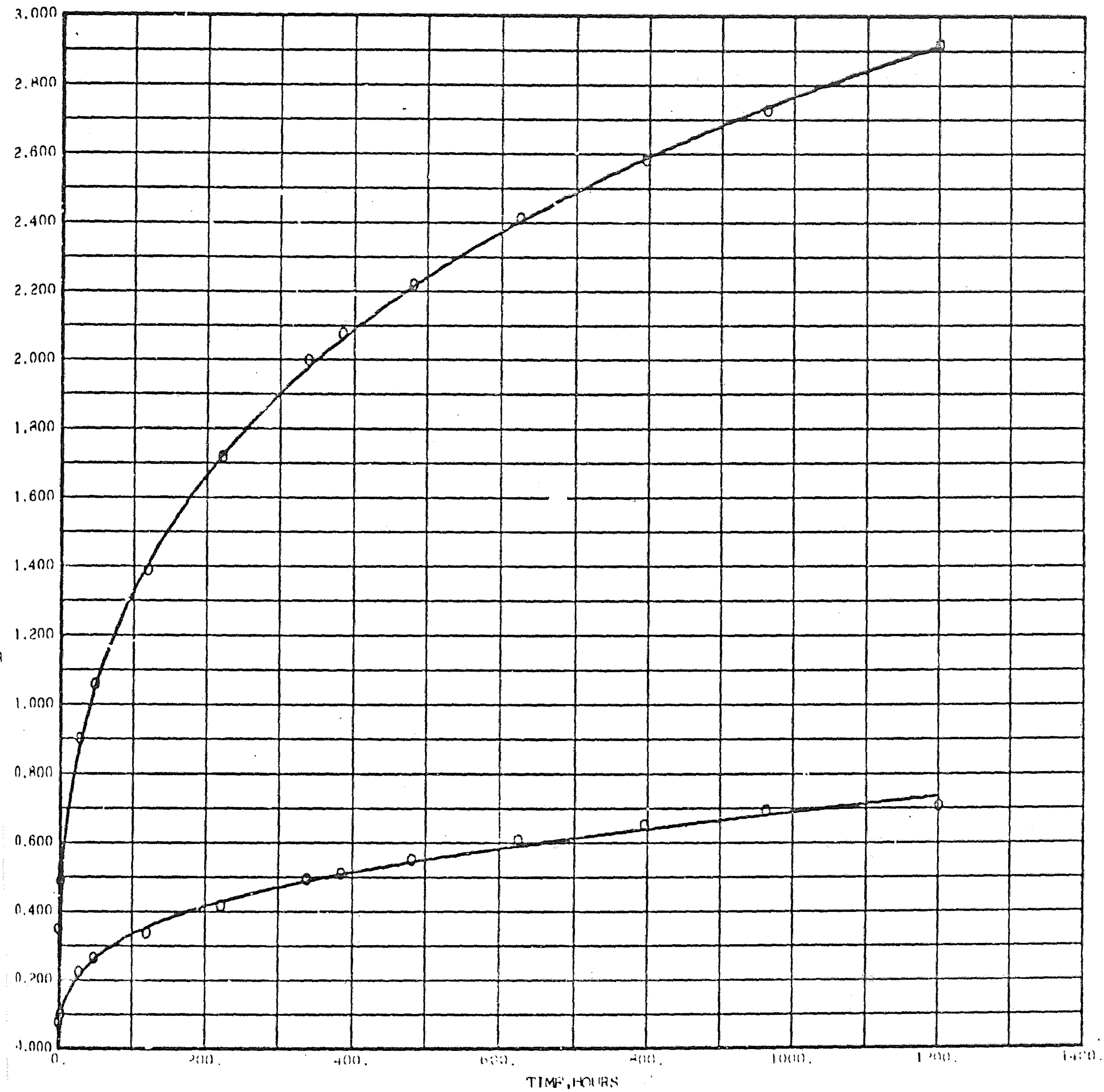
STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.5221E-05
STANDARD DEVIATION FOR ALL TIME = 0.5221E-05

....

JOB C0674
BOX M274,M2908,M274,HAL
TIME 11.321 HRS
DATE 03/27/72
NO. 1

44

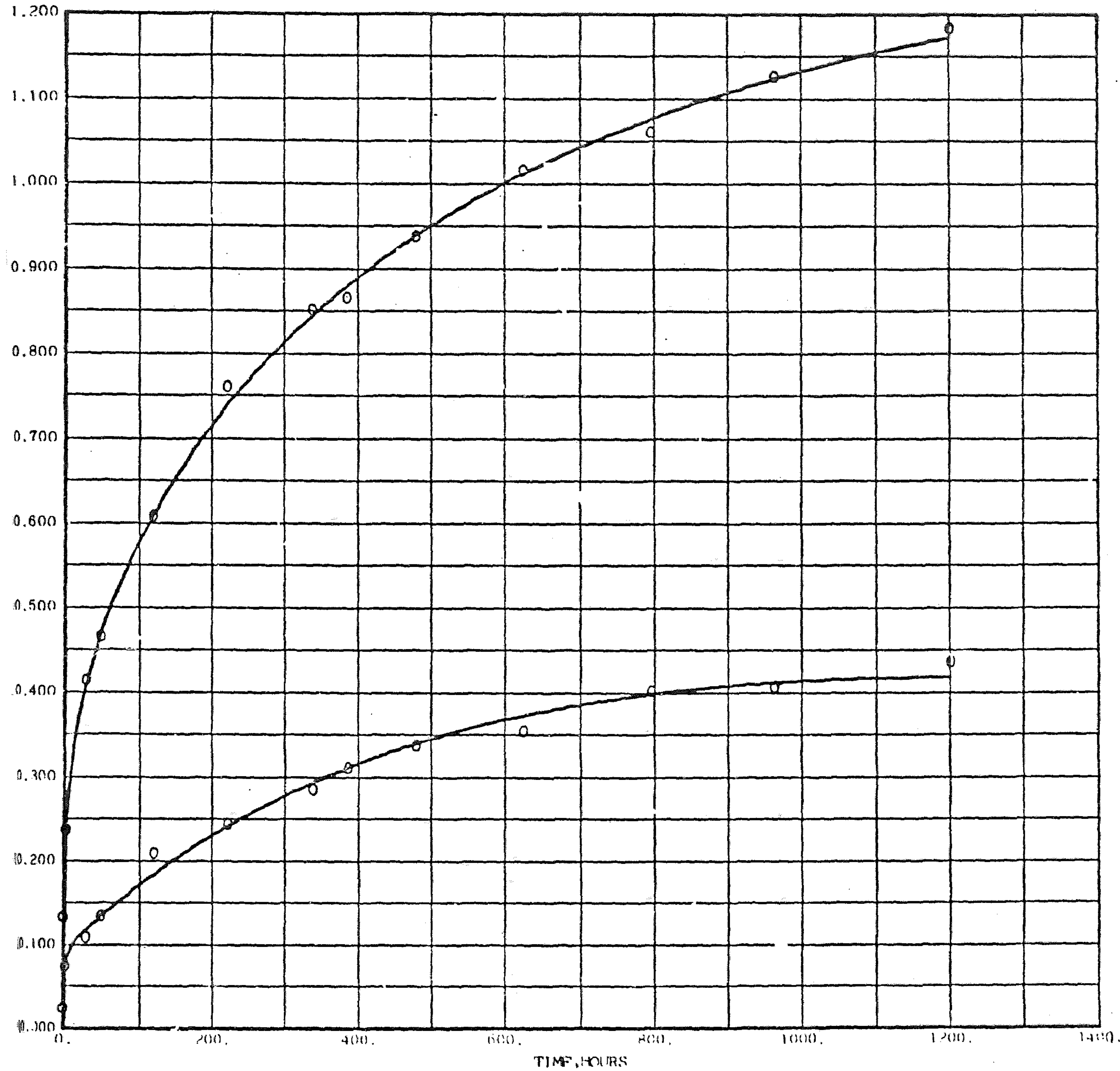
CREEP OF OFHC COPPER WIRE WITH 25 OZ PER TON OF SILVER
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =1 TEMPERATURE =250 DEG F



CU6?3
M274,M2908,M274,HAL
F 11.321 HRS
F 03/27/7-
NO 2

46 45

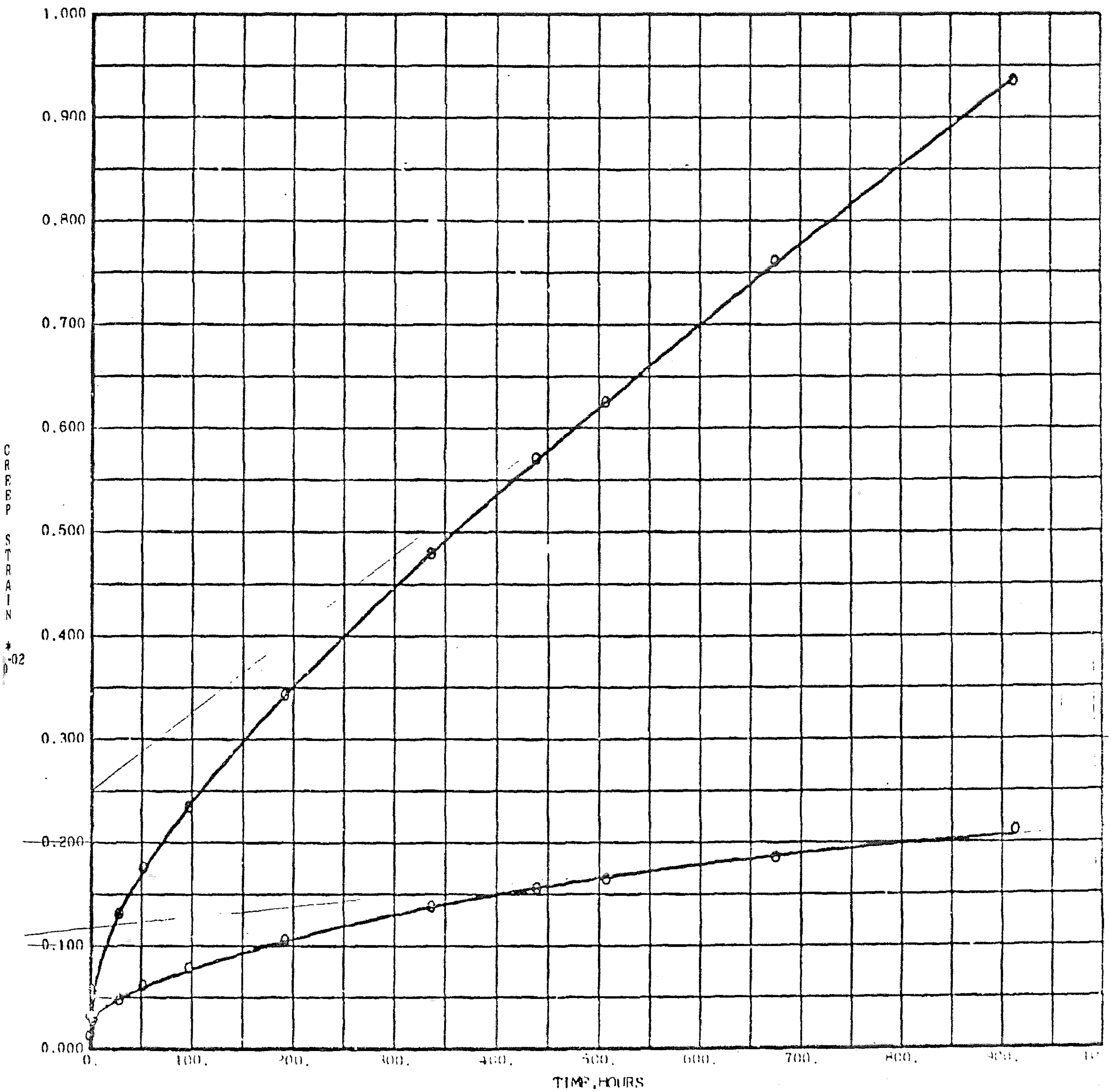
CREEP OF OFHC COPPER WIRE WITH 40 OZ PER TON OF SILVER
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =2 TEMPERATURE = 250 DEG F



47

46

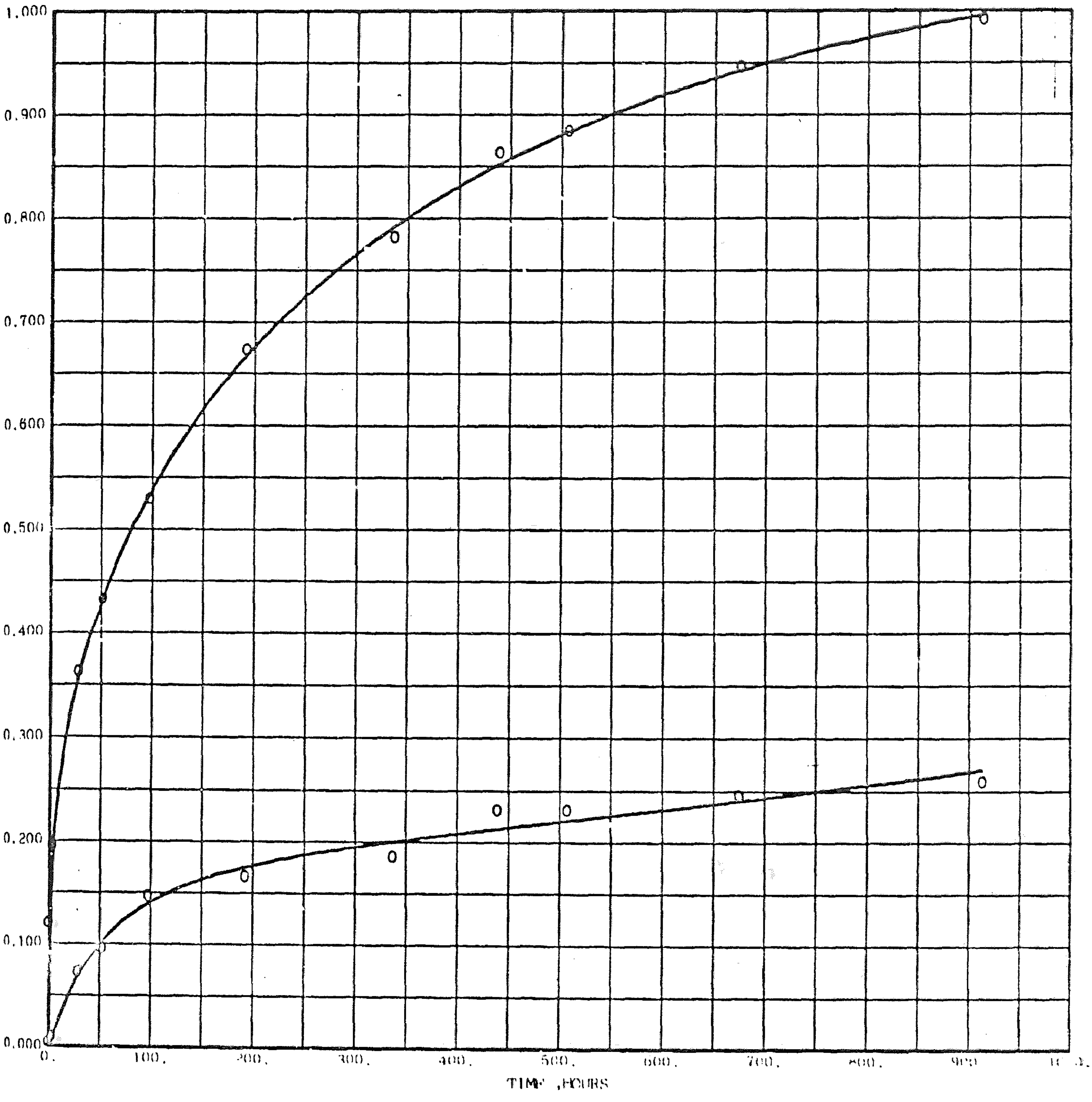
CREEP OF ETP COPPER WIRE COLD WORKED 10 PERCENT
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 3 TEMPERATURE = 250 DEG F



B C0673
X M274,M2908,M274,HAL
ME 11.321 HRS
TE 03/27/7?
NO 4

~~48~~
47

CREEP OF OFHC COPPER WIRE WITH 60 OZ PER TON OF SILVER
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =4 TEMPERATURE = 250 DEG F



4 1
2 4 1.0 0.01
CREEP OF HIGH PURITY (99.999+) COPPER
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 1 TEMPERATURE = 250 DEG F
NONE
CREEP STRAIN
NONE
TIME, HOURS
HIGH PURITY(99.999+)PERCENT COPPER AT 250 DEG F
52731 14 250.0 0.0201 36.0 2 2 12
10.0 19.7
0.0 36.1004 36.1511 36.1310 36.1076
1.0 36.1039 36.1547 36.1473 36.1225
4.0 36.1061 36.1591 36.1618 36.1381
30.0 36.1143 36.1662 36.2041 36.1907
52.7 36.1253 36.1778 36.2438 36.2345
98.0 36.1337 36.1888 36.3399 36.3810
193.0 36.1681 36.2032 0 0
337.0 36.4080 36.2839 0 0
439.2 36.6177 36.4322 0 0
507.0 36.7585 36.5833 0 0
675.0 36.9745 37.9042 0.0 0.0
913.0 37.0880 37.0976 0.0 0.0
2 4 1.0 0.01
CREEP OF HIGH PURITY (99.999+)COPPER WIRE WITH 25 OZ PER TON OF SILVER
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =2 TEMPERATURE = 250 DEG F
NONE
CREEP STRAIN
NONE
TIME ,HOURS
HIGH PURITY (99.999+)PERCENT COPPER WIRE WITH 25 OZ PER TON OF SILVER
52731 14 250.0 0.0201 36.0 2 2 12
10.0 21.6
0.0 36.0596 36.0817 36.0846 36.1013
1.0 36.0621 36.0830 36.0957 36.1124
4.0 36.0636 36.0862 36.1032 36.1216
30.0 36.0696 36.0908 36.1204 36.1386
52.7 36.0738 36.0940 36.1300 36.1500
98.0 36.0746 36.0962 36.1396 36.1648
193.0 36.0801 36.1003 36.1537 36.1732
337.0 36.0822 36.1053 36.1693 36.1890
439.2 36.0848 36.1057 36.1756 36.1974
507.0 36.0864 36.1072 36.1820 36.2006
675.0 36.0886 36.1100 36.1960 36.2102
913.0 36.0927 36.1113 36.2024 36.2229
2 4 1.0 0.01
CREEP OF HIGH PURITY (99.999+)PERCENT COPPER WIRE
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 3 TEMPERATURE = 200 DEG F
NONE
CREEP STRAIN
NONE
TIME,HOURS
HIGH PURITY (99.999+)PERCENT COPPER WIRE
52731 20 200.0 0.0201 36.0 2 2 12
10.0 19.7
0.0 36.0191 36.0304 36.0571 36.0768
1.0 36.0215 36.0357 36.0671 36.0876
23.0 36.0275 36.0431 36.0868 36.1092
94.0 36.0335 36.0503 36.1151 36.1351

201.6	36.0379	36.0571	36.1410	36.1601
311.8	36.0430	36.0617	36.1694	36.1852
359.8	36.0449	36.0631	36.1790	36.1927
455.0	36.0469	36.0664	36.2000	36.2114
601.0	36.0500	36.0696	36.2306	36.2372
765.9	36.0530	36.0742	36.2639	36.2667
954.3	36.0569	36.0766	36.3109	36.3043
1174.6	36.0600	36.0799	36.3783	36.3565

2 4 1.0 0.01
CREEP OF HIGH PURITY (99.999+)PERCENT COPPER WITH 25 OZ PER TON OF SILVER
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 4 TEMPERATURE = 200 DEG F
NONE
CREEP STRAIN
NONE
TIME,HOURS
HIGH PURITY COPPER WIRE WITH 25 OZ PER TON OF SILVER
52731 20 200.0 0.0201 36.0 2 2 12
10.0 21.6

0.0	36.0339	36.0351	36.0504	36.0575
1.0	36.0358	36.0390	36.0593	36.0654
23.0	36.0398	36.0440	36.0737	36.0800
94.0	36.0444	36.0471	36.0861	36.0915
201.6	36.0473	36.0499	36.0950	36.0994
311.8	36.0487	36.0510	36.1014	36.1057
359.8	36.0499	36.0513	36.1039	36.1070
455.0	36.0521	36.0537	36.1081	36.1110
601.0	36.0523	36.0547	36.1124	36.1147
765.9	36.0540	36.0563	36.1160	36.1195
954.3	36.0541	36.0571	36.1204	36.1226
1174.6	36.0560	36.0576	36.1242	36.1263

SNUMB = C0057, ACTIVITY # = 01, REPORT CODE = 06, RECORD COUNT = 00383

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DATA SET NUMBER 1

NOTEBOOK NUMBER 52731 PAGE 14
MATERIAL:HIGH PURITY(99.999+)PERCENT COPPER A
MATERIAL:T 250 DEG F
CREEP TEST
TEMPERATURE (IN DEGREES F):250.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 36.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.9861E-04	0.9649E-04	2.14
4.0	0.1903E-03	0.2051E-03	7.80
30.0	0.4028E-03	0.3810E-03	5.40
52.7	0.7167E-03	0.5687E-03	20.64
98.0	0.9861E-03	0.1058E-02	7.29
193.0	0.1664E-02	0.2597E-02	56.08
337.0	0.6117E-02	0.6351E-02	3.83
439.2	0.1109E-01	0.1012E-01	8.76
507.0	0.1514E-01	0.1314E-01	13.25
675.0	0.3649E-01	0.2244E-01	38.49
913.0	0.2686E-01	0.4007E-01	49.18

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.9246E 01
C(2) = 0.1029E 01
C(3) = -0.4945E 00
C(4) = 0.1131E 00
C(5) = -0.6413E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.5860E-02
STANDARD DEVIATION FOR ALL TIME = 0.5860E-02

STRESS LEVEL NO. 2 NOMINALSTRESS = 19.70 KPSI

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TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.4333E-03	0.4333E-03	0.00
4.0	0.8514E-03	0.8514E-03	0.00
30.0	0.2169E-02	0.2169E-02	0.00
52.7	0.3329E-02	0.3329E-02	0.00
98.0	0.6699E-02	0.6699E-02	0.00

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.7744E 01
C(2) = 0.5170E 00
C(3) = 0.3751E-02
C(4) = -0.2742E-01
C(5) = 0.6634E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.1846E-07
STANDARD DEVIATION FOR ALL TIME = 0.1846E-07

....

ONLY STARE OUTPUT CALLED FOR

D A T A S E T N U M B E R 2

NOTEBOOK NUMBER 52731 PAGE 14
MATERIAL:HIGH PURITY (99.999+)PERCENT COPPER
MATERIAL:WIRE WITH 25 OZ PER TON OF SILVER
CREEP TEST
TEMPERATURE (IN DEGREES F):250.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 36.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.5278E-04	0.5287E-04	0.16
4.0	0.1181E-03	0.1172E-03	0.70
30.0	0.2653E-03	0.2784E-03	4.96
52.7	0.3681E-03	0.3424E-03	6.96
98.0	0.4097E-03	0.4256E-03	3.86
193.0	0.5431E-03	0.5342E-03	1.63
337.0	0.6417E-03	0.6396E-03	0.33
439.2	0.6833E-03	0.6952E-03	1.73
507.0	0.7264E-03	0.7268E-03	0.06
675.0	0.7958E-03	0.7932E-03	0.33
913.0	0.8708E-03	0.8678E-03	0.34

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CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.9848E 01
C(2) = 0.6628E 00
C(3) = -0.7397E-01
C(4) = 0.7926E-02
C(5) = -0.3675E-03

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.1095E-04
STANDARD DEVIATION FOR ALL TIME = 0.1095E-04

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 21.60 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.3083E-03	0.3091E-03	0.26

4.0	0.5403E-03	0.5346E-03	1.05
30.0	0.1015E-02	0.1060E-02	4.41
52.7	0.1307E-02	0.1281E-02	1.99
98.0	0.1646E-02	0.1581E-02	3.95
193.0	0.1958E-02	0.1992E-02	1.72
337.0	0.2394E-02	0.2405E-02	0.46
439.2	0.2599E-02	0.2627E-02	1.09
507.0	0.2732E-02	0.2754E-02	0.80
675.0	0.3060E-02	0.3020E-02	1.30
913.0	0.3325E-02	0.3318E-02	0.21

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53

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.8382E 01
C(2) = 0.4453E 00
C(3) = -0.4674E-01
C(4) = 0.8361E-02
C(5) = -0.5274E-03

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.3179E-04
STANDARD DEVIATION FOR ALL TIME = 0.3179E-04

....

D A T A S E T N U M B E R 3

NOTEBOOK NUMBER 52731 PAGE 20
MATERIAL:HIGH PURITY (99.999+)PERCENT COPPER
MATERIAL:WIRE
CREEP TEST
TEMPERATURE (IN DEGREES F):200.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 36.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.) CREEP STRAIN BEST FIT PERCENT ERROR

1.0	0.1069E-03	0.1069E-03	0.00
23.0	0.2931E-03	0.2930E-03	0.00
94.0	0.4764E-03	0.4755E-03	0.20
201.6	0.6319E-03	0.6392E-03	1.15
311.8	0.7667E-03	0.7608E-03	0.76
359.8	0.8125E-03	0.8056E-03	0.85
455.0	0.8861E-03	0.8840E-03	0.24
601.0	0.9736E-03	0.9848E-03	1.15
765.9	0.1079E-02	0.1079E-02	0.06
954.3	0.1167E-02	0.1167E-02	0.05
1174.6	0.1256E-02	0.1253E-02	0.22

~~58~~ 57

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.9143E 01
C(2) = 0.4406E 00
C(3) = -0.3515E-01
C(4) = 0.1890E-01
C(5) = -0.1231E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.4985E-05
STANDARD DEVIATION FOR ALL TIME = 0.4985E-05

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 19.70 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.2889E-03	0.2889E-03	0.01
23.0	0.8625E-03	0.8614E-03	0.13
94.0	0.1615E-02	0.1619E-02	0.20
201.6	0.2322E-02	0.2358E-02	1.55
311.8	0.3065E-02	0.3010E-02	1.80
359.8	0.3303E-02	0.3283E-02	0.59
455.0	0.3854E-02	0.3820E-02	0.89
601.0	0.4637E-02	0.4648E-02	0.23
765.9	0.5510E-02	0.5612E-02	1.86
954.3	0.6685E-02	0.6768E-02	1.25
1174.6	0.8346E-02	0.8210E-02	1.62

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.8149E 01
C(2) = 0.1003E 00
C(3) = 0.1518E 00
C(4) = -0.3650E-01
C(5) = 0.2333E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.6169E-04
STANDARD DEVIATION FOR ALL TIME = 0.6169E-04

....

D A T A   S E T   N U M B E R   4

NOTEBOOK NUMBER 52731 PAGE 20
MATERIAL:HIGH PURITY COPPER WIRE WITH 25 OZ P
MATERIAL:ER TON OF SILVER
CREEP TEST
TEMPERATURE (IN DEGREES F):200.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 36.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.8056E-04	0.8055E-04	0.01
23.0	0.2056E-03	0.2062E-03	0.29
94.0	0.3125E-03	0.3093E-03	1.03
201.6	0.3917E-03	0.3880E-03	0.93
311.8	0.4264E-03	0.4408E-03	3.38
359.8	0.4472E-03	0.4593E-03	2.69
455.0	0.5111E-03	0.4905E-03	4.03
601.0	0.5278E-03	0.5288E-03	0.19
765.9	0.5736E-03	0.5627E-03	1.91
954.3	0.5861E-03	0.5933E-03	1.22
1174.6	0.6195E-03	0.6216E-03	0.34

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.9427E 01
C(2) = 0.3631E 00
C(3) = -0.5393E-01
C(4) = 0.1109E-01
C(5) = -0.7562E-03

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.9429E-05

STANDARD DEVIATION FOR ALL TIME = 0.9429E-05

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56

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 21.60 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.2333E-03	0.2333E-03	0.00
23.0	0.6361E-03	0.6366E-03	0.07
94.0	0.9681E-03	0.9641E-03	0.41
201.6	0.1201E-02	0.1210E-02	0.70
311.8	0.1378E-02	0.1375E-02	0.17
359.8	0.1431E-02	0.1434E-02	0.24
455.0	0.1544E-02	0.1534E-02	0.68
601.0	0.1656E-02	0.1659E-02	0.19
765.9	0.1772E-02	0.1772E-02	0.00
954.3	0.1876E-02	0.1878E-02	0.10
1174.6	0.1981E-02	0.1980E-02	0.02

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

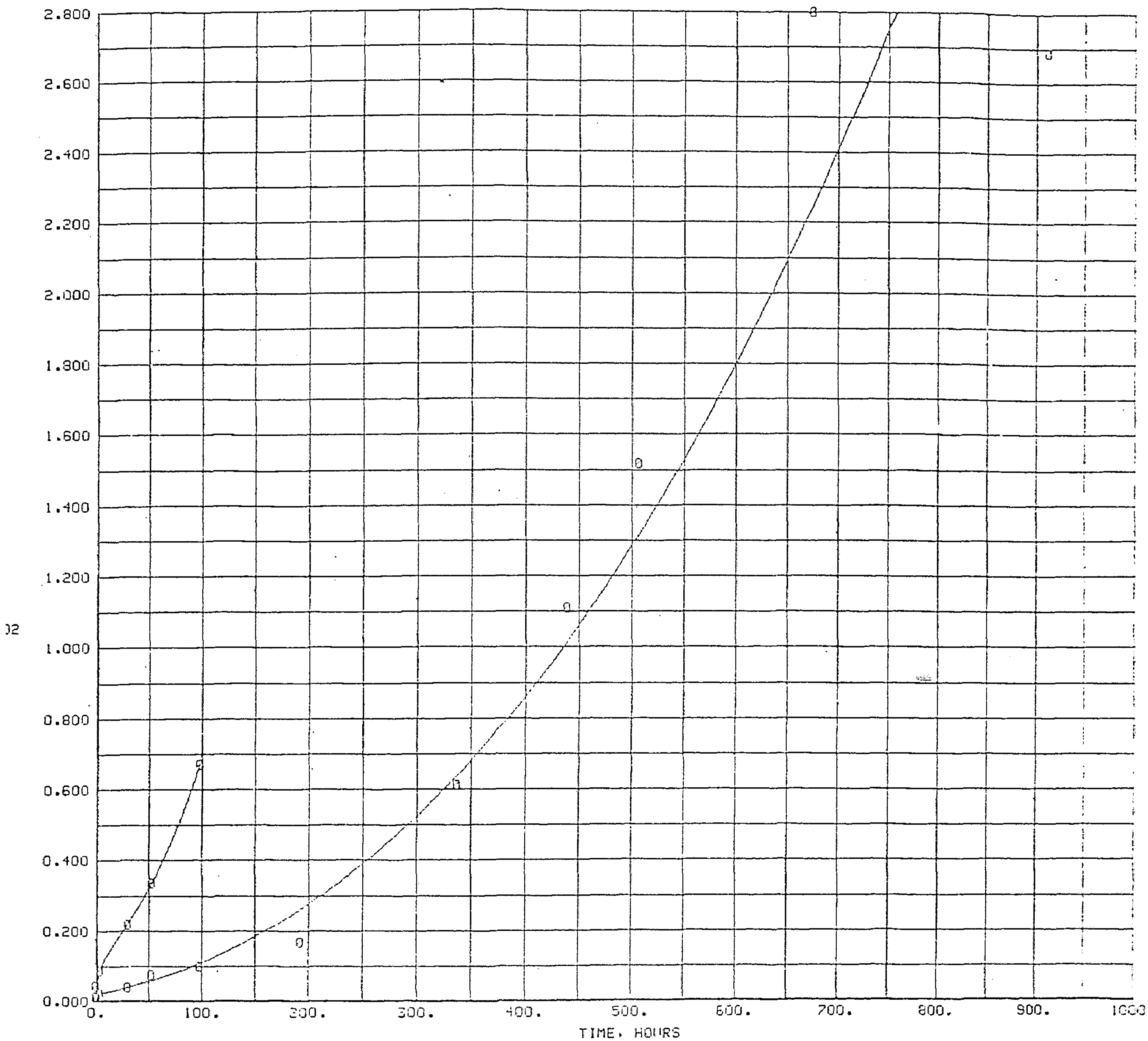
C(1) = -0.3363E 01
C(2) = 0.3917E 00
C(3) = -0.4160E-01
C(4) = 0.7431E-02
C(5) = -0.4732E-03

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.4546E-05
STANDARD DEVIATION FOR ALL TIME = 0.4546E-05

....

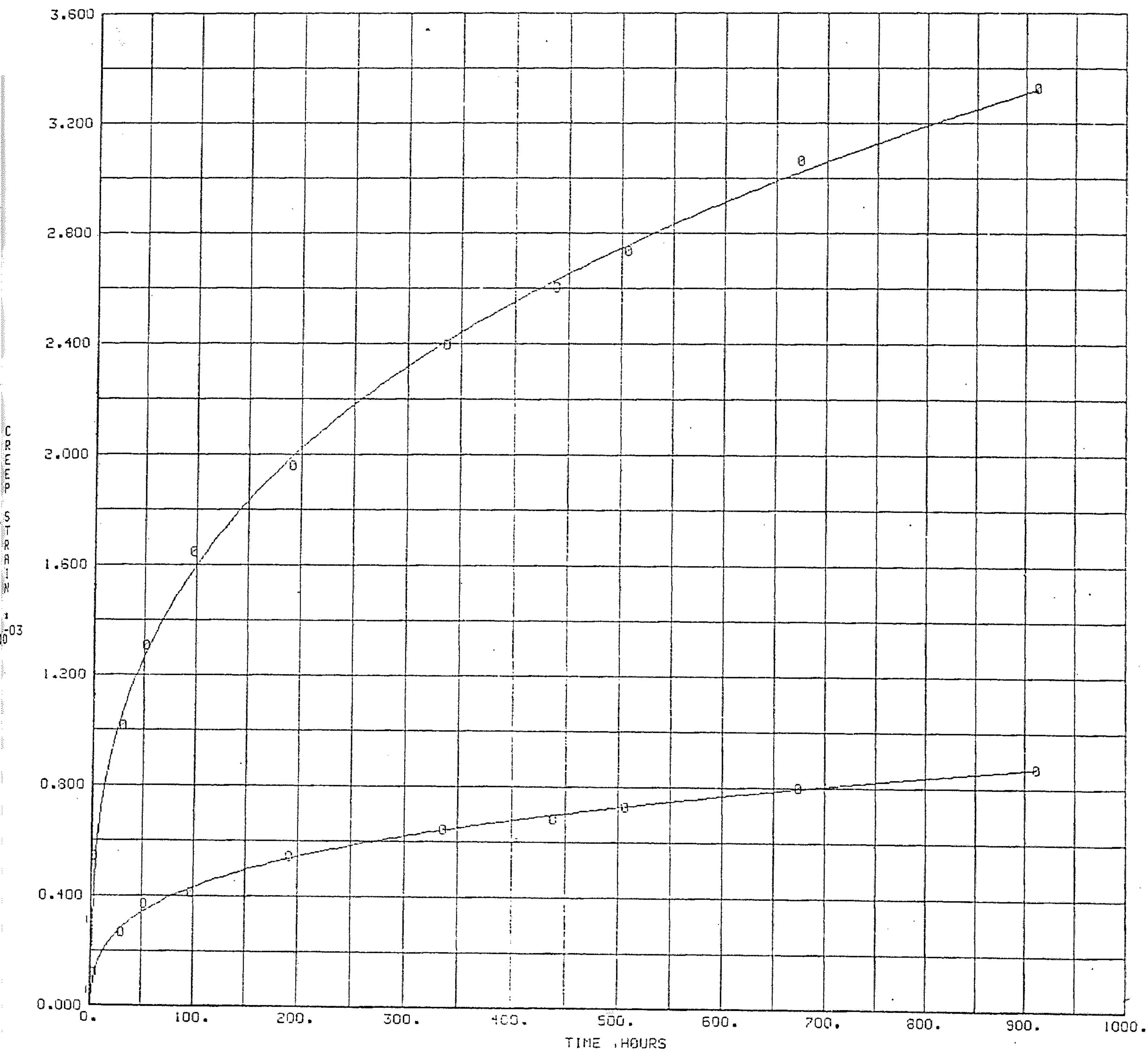
~~58~~
57

CREEP OF HIGH PURITY (99.999+) COPPER
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 1 TEMPERATURE = 250 DEG F



~~59~~ 58

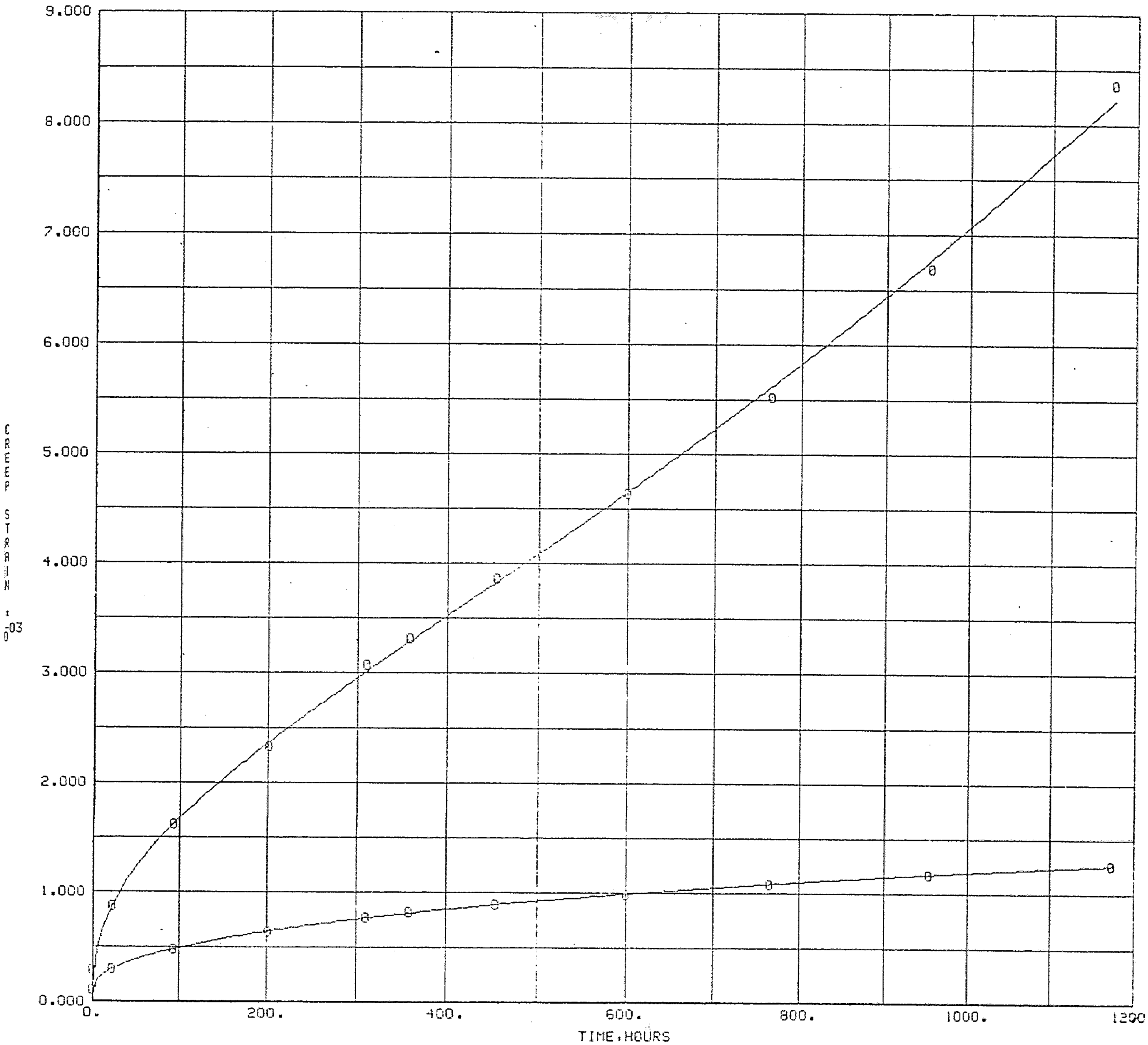
CREEP OF HIGH PURITY (99.999+)COPPER WIRE WITH 25 OZ PER TON OF SILVER
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =2 TEMPERATURE = 250 DEG F



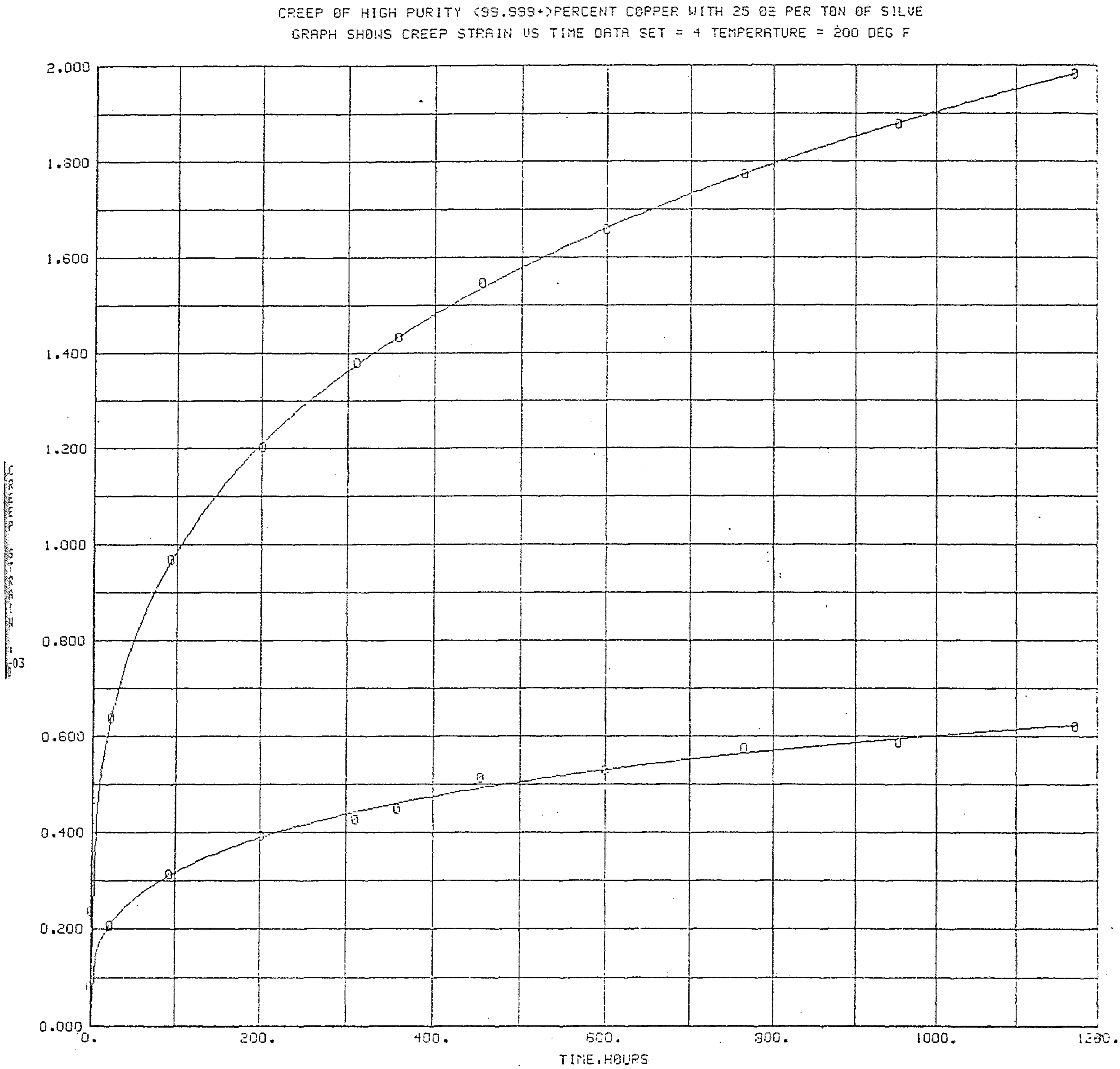
NUMB C0057 14.439 04/04
BOXM274,HAL
PAGE NO 03

~~60~~ 59

CREEP OF HIGH PURITY (99.999+)PERCENT COPPER WIRE
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 3 TEMPERATURE = 200 DEG F



~~61~~ 60


CREEP OF HIGH PURITY (99.999+)PERCENT COPPER WITH 25 OZ PER TON OF SILVE
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 4 TEMPERATURE = 200 DEG F
2.000
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
CREEP STRAIN
-03
0.
200.
400.
600.
800.
1000.
1200.
TIME,HOURS

4 1
2 4 1.0 0.01
CREEP OF ETP COPPER WIRE WITH 25 OZ PER TON OF SILVER
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =1 TEMPERATURE = 200.0DEG F
NONE
CREEP STRAIN
NONE
TIME ,HOURS
ETP COPPER WIRE WITH 25 OZ PER TON OF AG AT 200 DEG F
52731 13 200.0 0.0201 36.0 2 2 13
10.0 20.7

0.0	36.0335	36.0329	36.0666	36.0748
1.0	36.0361	36.0351	36.0741	36.0799
4.0	36.0380	36.0368	36.0757	36.0854
24.3	36.0400	36.0388	36.0833	36.0958
96.0	36.0431	36.0424	36.0928	36.1033
198.0	36.0448	36.0439	36.1000	36.1093
312.5	36.0466	36.0471	36.1087	36.1153
360.5	36.0480	36.0471	36.1092	36.1181
456.0	36.0497	36.0485	36.1093	36.1176
600.2	36.0511	36.0489	36.1141	36.1250
770.6	36.0511	36.0506	36.1166	36.1250
937.5	36.0523	36.0514	36.1192	36.1298
1175.9	36.0533	36.0527	36.1214	36.1305

Job #6
Duplicate
Run 3/25/72

(59) (62) (61)

2 4 1.0 0.01
CREEP OF ETP COPPER WIRE WITH 60 OZ PER TON OF SILVER
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 2 TEMPERATURE = 200 DEG F
NONE
CREEP STRAIN
NONE
TIME, HOURS
ETP COPPER WIRE WITH 60 OZ PER TON OF SILVER AT 200 DEG F
52731 13 200.0 0.0201 36.0 2 2 13
10.0 21.4

0.0	36.0384	36.0510	36.0693	36.0779
1.0	36.0391	36.0537	36.0745	36.0833
4.0	36.0404	36.0540	36.0775	36.0864
24.3	36.0416	36.0549	36.0819	36.0934
96.0	36.0453	36.0556	36.0890	36.0978
198.0	36.0469	36.0592	36.0926	36.1017
312.5	36.0473	36.0592	36.0961	36.1042
360.5	36.0480	36.0618	36.0979	36.1042
456.0	36.0483	36.0626	36.0987	36.1061
600.2	36.0502	36.0646	36.1010	36.1089
770.6	36.0502	36.0649	36.1022	36.1091
937.5	36.0517	36.0649	36.1045	36.1121
1175.9	36.0517	36.0650	36.1057	36.1122

2 4 1.0 0.01
CREEP OF OFHC COPPER WIRE
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 3 TEMPERATURE = 200 DEG F
NONE
CREEP STRAIN
NONE
TIME,HOURS
OFHC COPPER WIRE AT 200 DEG F
52731 17 200.0 0.0201 36.0 2 1 12
10.0

0.0	36.0409	36.0379
1.0	36.0446	36.0406

```
  23.0 36.0503 36.0454
  94.0 36.0536 36.0487
 201.6 36.0566 36.0518
 311.8 36.0582 36.0540
 359.8 36.0587 36.0537
 455.0 36.0605 36.0563
 601.0 36.0606 36.0564
 765.9 36.0630 36.0593
 954.3 36.0645 36.0607
1174.6 36.0654 36.0630
2 4 1.0 0.01
CREEP OF OFHC COPPER WIRE
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 4 TEMPERATURE = 200 DEG F
NONE
CREEP STRAIN
NONE
TIME,HOURS
OFHC COPPER WIRE AT 200 DEG F
52731 17 200.0 0.0201 36.0 2 1-13
20.6
   0.0 36.0843 36.0717
   1.0 36.0953 36.0830
   4.0 36.1010 36.0882
  24.0 36.1122 36.0989
  96.0 36.1281 36.1130
 198.0 36.1396 36.1237
 312.5 36.1493 36.1325
 360.5 36.1541 36.1357
 456.0 36.1576 36.1398
 600.2 36.1667 36.1483
 770.6 36.1752 36.1558
 937.5 36.1824 36.1628
1175.9 36.1928 36.1708
```

60

63

62

SNUMB = C0801, ACTIVITY # = 01, REPORT CODE = 06, RECORD COUNT = 00323

~~64~~
63

D A T A   S E T   N U M B E R   1

NOTEBOOK NUMBER 52731   PAGE 13
MATERIAL:ETP COPPER WIRE WITH 25 OZ.PER TON O
MATERIAL:F AG AT 200 DEG F
CREEP TEST
TEMPERATURE (IN DEGREES F):200.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 36.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1   NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.6666E-04	0.6672E-04	0.09
4.0	0.1167E-03	0.1162E-03	0.41
24.3	0.1722E-03	0.1746E-03	1.39
96.0	0.2653E-03	0.2553E-03	3.76
198.0	0.3097E-03	0.3247E-03	4.83
312.5	0.3792E-03	0.3791E-03	0.02
360.5	0.3986E-03	0.3975E-03	0.27
456.0	0.4417E-03	0.4288E-03	2.92
600.2	0.4667E-03	0.4657E-03	0.20
770.6	0.4903E-03	0.4982E-03	1.63
937.5	0.5181E-03	0.5218E-03	0.73
1175.9	0.5500E-03	0.5455E-03	0.82

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.9615E 01
C(2) = 0.5929E 00
C(3) = -0.1865E 00
C(4) = 0.3752E-01
C(5) = -0.2413E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.7044E-05
STANDARD DEVIATION FOR ALL TIME = 0.7044E-05

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 20.70 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.1750E-03	0.1743E-03	0.37
4.0	0.2736E-03	0.2778E-03	1.52
24.3	0.5236E-03	0.5057E-03	3.42
96.0	0.7597E-03	0.7839E-03	3.18
198.0	0.9431E-03	0.9747E-03	3.35
312.5	0.1147E-02	0.1111E-02	3.20
360.5	0.1193E-02	0.1155E-02	3.16
456.0	0.1188E-02	0.1231E-02	3.67
600.2	0.1357E-02	0.1323E-02	2.52
770.6	0.1392E-02	0.1408E-02	1.19
937.5	0.1494E-02	0.1476E-02	1.21
1175.9	0.1535E-02	0.1556E-02	1.37

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.8654E 01
C(2) = 0.3369E 00
C(3) = -0.8156E-03
C(4) = 0.2710E-03
C(5) = -0.9920E-04

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.2710E-04
STANDARD DEVIATION FOR ALL TIME = 0.2710E-04

....

D A T A S E T N U M B E R 2

NOTEBOOK NUMBER 52731 PAGE 13
MATERIAL:ETP COPPER WIRE WITH 60 OZ PER TON O
MATERIAL:F SILVER AT 200 DEG F
CREEP TEST
TEMPERATURE (IN DEGREES F):200.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 36.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.4722E-04	0.4724E-04	0.05
4.0	0.6944E-04	0.6928E-04	0.23
24.3	0.9861E-04	0.9932E-04	0.72
96.0	0.1597E-03	0.1597E-03	0.04
198.0	0.2319E-03	0.2173E-03	6.32
312.5	0.2375E-03	0.2634E-03	10.90
360.5	0.2833E-03	0.2789E-03	1.57
456.0	0.2986E-03	0.3047E-03	2.05
600.2	0.3528E-03	0.3340E-03	5.31
770.6	0.3569E-03	0.3579E-03	0.27
937.5	0.3778E-03	0.3732E-03	1.21
1175.9	0.3792E-03	0.3855E-03	1.66

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.9960E 01
C(2) = 0.4430E 00
C(3) = -0.1767E 00
C(4) = 0.4515E-01
C(5) = -0.3266E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.1063E-04
STANDARD DEVIATION FOR ALL TIME = 0.1063E-04

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 21.40 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.1472E-03	0.1471E-03	0.09
4.0	0.2319E-03	0.2328E-03	0.37
24.3	0.3903E-03	0.3874E-03	0.74
96.0	0.5500E-03	0.5518E-03	0.33
198.0	0.6542E-03	0.6596E-03	0.84
312.5	0.7375E-03	0.7359E-03	0.21
360.5	0.7625E-03	0.7612E-03	0.17
456.0	0.8000E-03	0.8040E-03	0.50
600.2	0.8708E-03	0.8563E-03	1.67
770.6	0.8903E-03	0.9056E-03	1.73
937.5	0.9639E-03	0.9455E-03	1.91
1175.9	0.9819E-03	0.9927E-03	1.10

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.8825E 01
C(2) = 0.3636E 00
C(3) = -0.2765E-01
C(4) = 0.3368E-02
C(5) = -0.1878E-03

66

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.8964E-05
STANDARD DEVIATION FOR ALL TIME = 0.8964E-05

....

D A T A S E T N U M B E R 3

NOTEBOOK NUMBER 52731 PAGE 17
MATERIAL:OFHC COPPER WIRE AT 200 DEG F
MATERIAL:
CREEP TEST
TEMPERATURE (IN DEGREES F):200.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 36.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.8888E-04	0.8889E-04	0.01
23.0	0.2347E-03	0.2340E-03	0.29
94.0	0.3264E-03	0.3313E-03	1.49
201.6	0.4111E-03	0.4049E-03	1.51
311.8	0.4639E-03	0.4573E-03	1.42
359.8	0.4667E-03	0.4765E-03	2.11
455.0	0.5278E-03	0.5105E-03	3.27
601.0	0.5305E-03	0.5553E-03	4.66
765.9	0.6042E-03	0.5987E-03	0.91
954.3	0.6444E-03	0.6421E-03	0.37
1174.6	0.6889E-03	0.6868E-03	0.30

CONSTANTS FOR CURVE FITTING:

~~68~~ 67

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.9328E 01
C(2) = 0.4318E 00
C(3) = -0.6137E-01
C(4) = 0.8029E-02
C(5) = -0.3113E-03

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.1024E-04
STANDARD DEVIATION FOR ALL TIME = 0.1024E-04

....

D A T A S E T N U M B E R 4

NOTEBOOK NUMBER 52731 PAGE 17
MATERIAL:OFHC COPPER WIRE AT 200 DEG F
MATERIAL:
CREEP TEST
TEMPERATURE (IN DEGREES F):200.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 36.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 20.60 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.3097E-03	0.3099E-03	0.07
4.0	0.4611E-03	0.4598E-03	0.29
24.0	0.7653E-03	0.7700E-03	0.62
96.0	0.1182E-02	0.1176E-02	0.51
198.0	0.1490E-02	0.1491E-02	0.02
312.5	0.1747E-02	0.1744E-02	0.17
360.5	0.1858E-02	0.1835E-02	1.27
456.0	0.1964E-02	0.1997E-02	1.70
600.2	0.2208E-02	0.2211E-02	0.13
770.6	0.2431E-02	0.2432E-02	0.07
937.5	0.2628E-02	0.2626E-02	0.07
1175.9	0.2883E-02	0.2875E-02	0.28

~~64~~ 68

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

```
C(1) =  -0.8079E 01
C(2) =   0.2864E 00
C(3) =  -0.2241E-02
C(4) =   0.5400E-03
C(5) =   0.4958E-04
```

```
STANDARD DEVIATION FOR TIME .GE.     1.0 HRS. =      0.1229E-04
STANDARD DEVIATION FOR ALL TIME =     0.1229E-04
```

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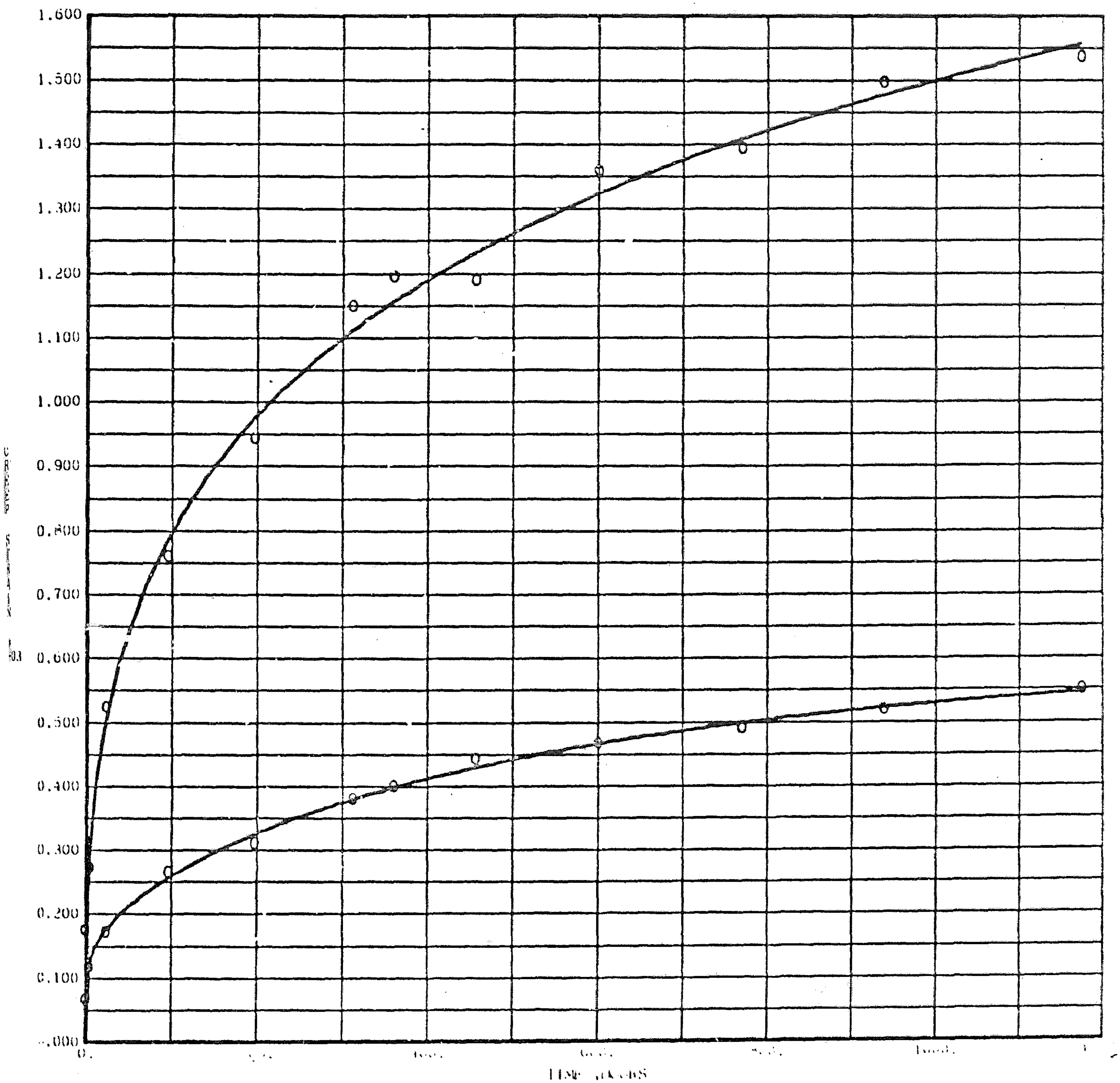
M274,M2908,M274,HAL
17,514 HRS
04/27/72
1

69

CREEP OF ETP COPPER WIRE WITH 25 OZ PER TON OF SILVER

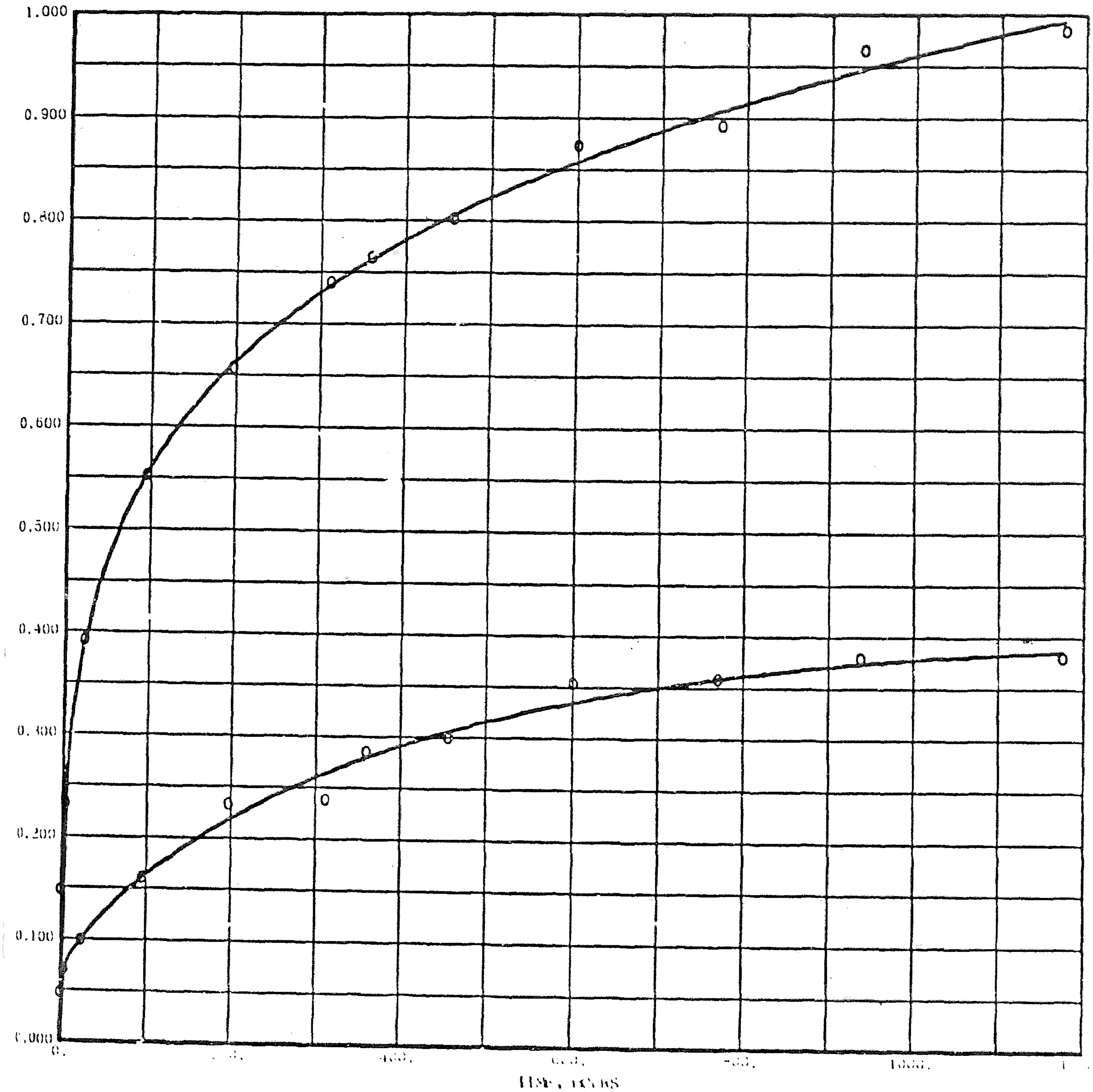
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =1 TEMPERATURE = 200.0DEG F



M274,M2908,M274,HAL.
17,514 HRS

~~68~~ ~~71~~ 70

CREEP OF ETP COPPER WIRE WITH 60 OZ PER TON OF SILVER
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 2 TEMPERATURE = 200 DEG F



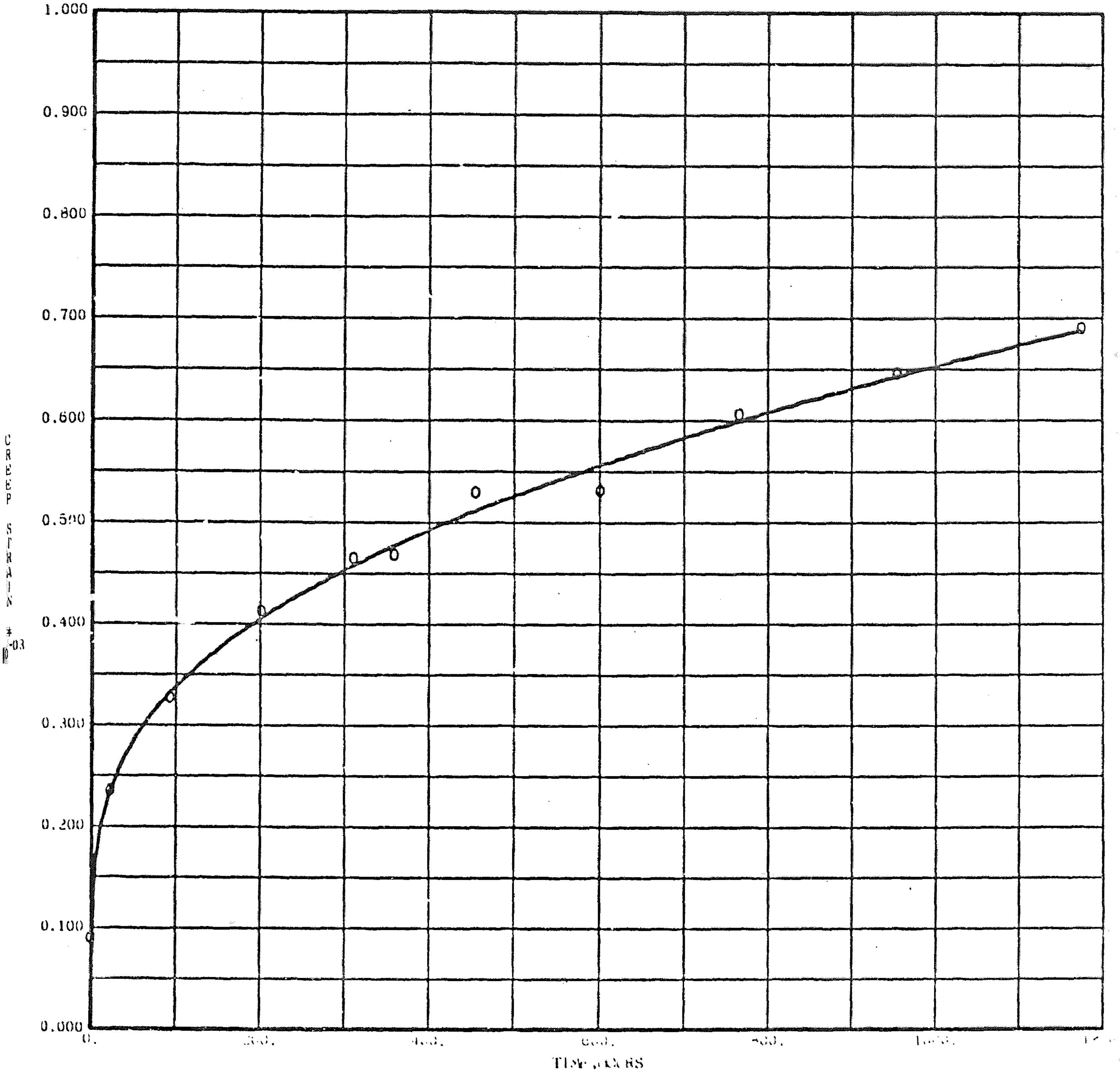
M274,M2904,M274

17.514 HRS

~~68~~ ~~70~~ 71

CREEP OF OFHC COPPER WIRE

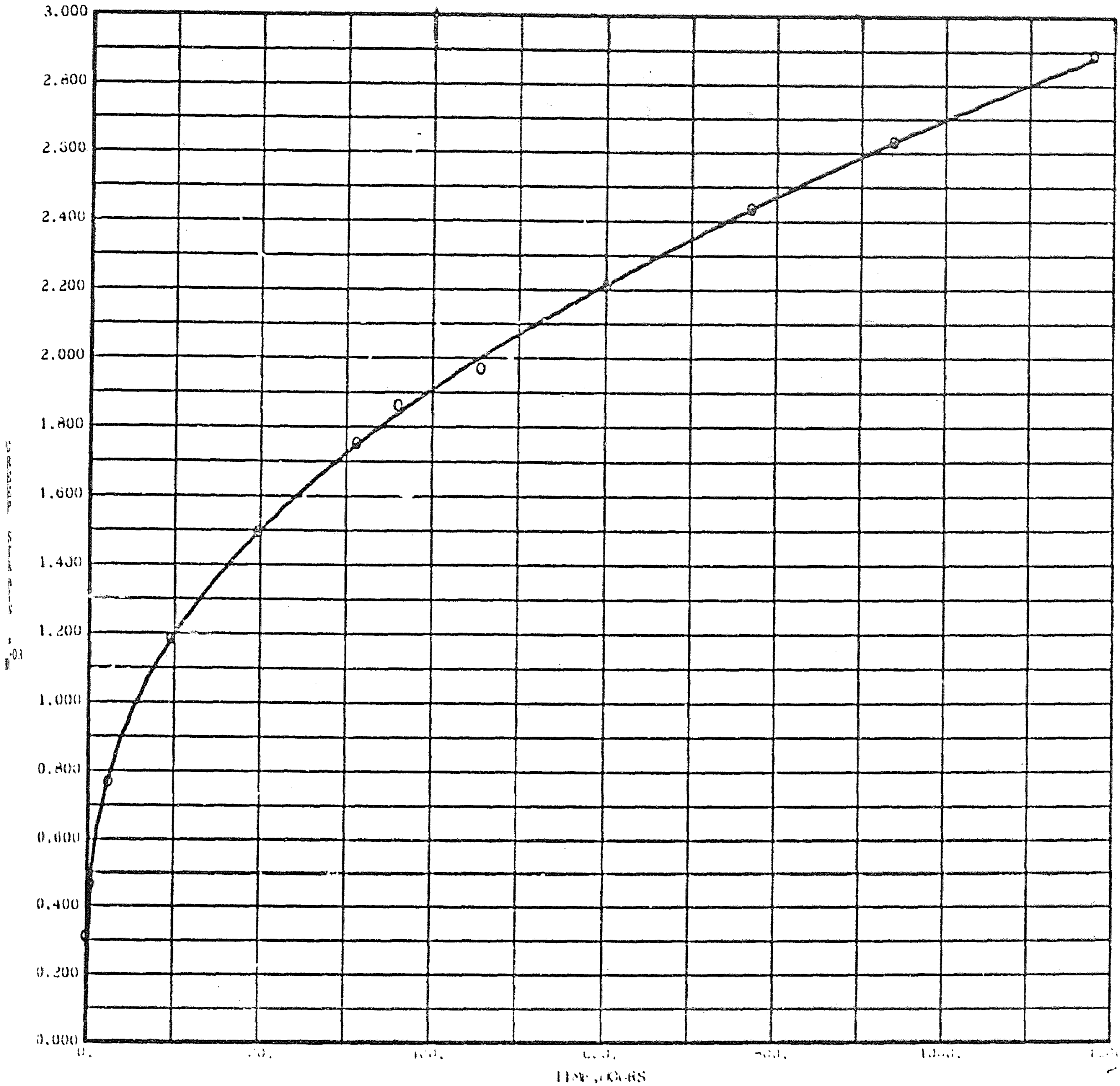
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 3 TEMPERATURE = 200 DEG F



TIME 17.514 HRS
DATE 03/27/72

67 70 73 72

CREEP OF OFHC COPPER WIRE
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 4 TEMPERATURE = 200 DEG F



```
4 1
2 4 1.0 0.01
CREEP OF OFHC COPPER WIRE WITH 25 OZ PER TON OF SILVER
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 1 TEMPERATURE = 200 DEG F
NONE
CREEP STRAIN
NONE
TIME ,HOURS
OFHC COPPER WIRE WITH 25 OZ PER TON OF SILVER
52731 17 200.0 0.0201 36.0 2 2 12
10.0 22.1
    0.0 36.0455 36.0156 36.0511 36.0747
    1.0 36.0468 36.0172 36.0548 36.0792
   23.0 36.0491 36.0191 36.0653 36.0870
   94.0 36.0510 36.0217 36.0725 36.0942
  201.6 36.0538 36.0234 36.0770 36.1004
  311.8 36.0553 36.0241 36.0820 36.1033
  359.8 36.0550 36.0248 36.0837 36.1036
  455.0 36.0567 36.0259 36.0865 36.1067
  601.0 36.0574 36.0264 36.0882 36.1097
  765.9 36.0587 36.0280 36.0913 36.1114
  954.3 36.0594 36.0283 36.0933 36.1141
 1174.6 36.0596 36.0290 36.0965 36.1161
2 4 1.0 0.01
CREEP OF OFHC COPPER WIRE WITH 40 OZ PER TON OF SILVER
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 2 TEMPERATURE = 200 DEG F
NONE
CREEP STRAIN
NONE
TIME,HOURS
OFHC COPPER WIRE WITH 40 OZ PER TON OF SILVER
52731 18 200.0 0.0201 36.0 2 2 12
10.0 18.7
    0.0 36.0365 36.0197 36.0525 36.0622
    1.0 36.0368 36.0265 36.0552 36.0648
   23.0 36.0381 36.0293 36.0595 36.0680
   94.0 36.0403 36.0293 36.0629 36.0725
  201.0 36.0417 36.0293 36.0656 36.0749
  311.8 36.0428 36.0293 36.0686 36.0766
  359.8 36.0433 36.0320 36.0689 36.0777
  455.0 36.0437 36.0320 36.0704 36.0781
  601.0 36.0440 36.0326 36.0704 36.0784
  765.9 36.0454 36.0327 36.0724 36.0806
  954.3 36.0446 36.0332 36.0734 36.0808
 1174.6 36.0449 36.0335 36.0741 36.0820
2 4 1.0 0.01
CREEP OF ETP COPPER WIRE COLD WORKED 10 PERCENT
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 3 TEMPERATURE = 200 DEG F
NONE
CREEP STRAIN
NONE
TIME ,HOURS
ETP COPPER WIRE COLD WORKED 10 PERCENT
52731 18 200.0 0.0201 36.0 2 2 13
10.0 17.5
    0.0 36.0307 36.0810 36.0700 36.0727
    1.0 36.0357 36.0867 36.0811 36.0829
    4.0 36.0385 36.0892 36.0874 36.0889
   24.0 36.0446 36.0957 36.1027 36.1040
```

JOB Nº 7

Ram
3/29/71

73

~~73~~ 74

```
  96.0 36.0538 36.1029 36.1221 36.1292
 198.0 36.0595 36.1080 36.1402 36.1420
 312.5 36.0657 36.1162 36.1552 36.1570
 360.5 36.0680 36.1181 36.1613 36.1638
 456.0 36.0700 36.1213 36.1707 36.1734
 600.2 36.0744 36.1233 36.1830 36.1871
 770.6 36.0783 36.1281 36.1986 36.2010
 937.5 36.0820 36.1319 36.2124 36.2142
1175.9 36.0861 36.1360 36.2308 36.2329
2 4 1.0 0.01
CREEP OF OFHC COPPER WIRE WITH 60 OZ PER TON OF SILVER
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =4 TEMPERATURE = 200 DEG F
NONE
CREEP STRAIN
NONE
TIME,HOURS
OFHC COPPER WIRE WITH 60 OZ PER TON OF SILVER
52731 19 200.0 0.0201 36.0 2 2 13
10.0 24.2
    0.0 36.0441 36.0339 36.1194 36.0577
    1.0 36.0443 36.0348 36.1259 36.0604
    4.0 36.0443 36.0348 36.1264 36.0604
   24.0 36.0455 36.0360 36.1307 36.0638
   96.0 36.0462 36.0366 36.1354 36.0666
  198.0 36.0462 36.0369 36.1389 36.0715
  312.0 36.0484 36.0393 36.1406 36.0716
  360.5 36.0484 36.0394 36.1421 36.0722
  456.0 36.0484 36.0389 36.1441 36.0740
  600.2 36.0484 36.0399 36.1445 36.0750
  770.6 36.0497 36.0404 36.1454 36.0769
  937.5 36.0500 36.0410 36.1462 36.0778
 1175.9 36.0500 36.0410 36.1471 36.0794
```

SNUMB = C0990, ACTIVITY # = 01, REPORT CODE = 06, RECORD COUNT = 00393

~~76~~ 75

D A T A   S E T   N U M B E R   1

NOTEBOOK NUMBER 52731   PAGE 17
MATERIAL:OFHC COPPER WIRE WITH 25 OZ PER TON
MATERIAL:OF SILVER
CREEP TEST
TEMPERATURE (IN DEGREES F):200.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 36.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1   NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.4028E-04	0.4028E-04	0.00
23.0	0.9861E-04	0.9861E-04	0.00
94.0	0.1611E-03	0.1622E-03	0.65
201.6	0.2236E-03	0.2172E-03	2.86
311.8	0.2542E-03	0.2559E-03	0.70
359.8	0.2597E-03	0.2697E-03	3.83
455.0	0.2986E-03	0.2929E-03	1.90
601.0	0.3153E-03	0.3213E-03	1.90
765.9	0.3556E-03	0.3459E-03	2.72
954.3	0.3694E-03	0.3674E-03	0.54
1174.6	0.3819E-03	0.3864E-03	1.16

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.1012E 02
C(2) = 0.3315E 00
C(3) = -0.5311E-01
C(4) = 0.1624E-01
C(5) = -0.1267E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.5470E-05
STANDARD DEVIATION FOR ALL TIME = 0.5470E-05

....

24

24

76

STRESS LEVEL NO. 2 NOMINALSTRESS = 22.10 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.1139E-03	0.1139E-03	0.00
23.0	0.3681E-03	0.3681E-03	0.00
94.0	0.5681E-03	0.5673E-03	0.14
201.6	0.7167E-03	0.7198E-03	0.44
311.8	0.8264E-03	0.8239E-03	0.31
359.8	0.8542E-03	0.8607E-03	0.76
455.0	0.9361E-03	0.9237E-03	1.33
601.0	0.1001E-02	0.1002E-02	0.07
765.9	0.1068E-02	0.1073E-02	0.46
954.3	0.1133E-02	0.1139E-02	0.46
1174.6	0.1206E-02	0.1201E-02	0.41

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.9080E 01
C(2) = 0.5293E 00
C(3) = -0.8549E-01
C(4) = 0.1412E-01
C(5) = -0.8418E-03

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.5136E-05
STANDARD DEVIATION FOR ALL TIME = 0.5136E-05

....

ONLY STARE OUTPUT CALLED FOR

D A T A S E T N U M B E R 2

NOTEBOOK NUMBER 52731 PAGE 18
MATERIAL:OFHC COPPER WIRE WITH 40 OZ PER TON
MATERIAL:OF SILVER
CREEP TEST
TEMPERATURE (IN DEGREES F):200.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 36.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.9861E-04	0.9858E-04	0.03
23.0	0.1556E-03	0.1568E-03	0.79
94.0	0.1861E-03	0.1787E-03	3.98
201.0	0.2056E-03	0.2132E-03	3.71
311.8	0.2208E-03	0.2401E-03	8.71
359.8	0.2653E-03	0.2495E-03	5.94
455.0	0.2708E-03	0.2652E-03	2.09
601.0	0.2833E-03	0.2829E-03	0.16
765.9	0.3042E-03	0.2961E-03	2.66
954.3	0.3000E-03	0.3049E-03	1.64
1174.6	0.3069E-03	0.3093E-03	0.76

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.9225E 01
C(2) = 0.7421E 00
C(3) = -0.3781E 00
C(4) = 0.7473E-01
C(5) = -0.4648E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.8842E-05
STANDARD DEVIATION FOR ALL TIME = 0.8842E-05

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 18.70 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.7361E-04	0.7361E-04	0.00
23.0	0.1778E-03	0.1777E-03	0.06
94.0	0.2875E-03	0.2870E-03	0.17
201.0	0.3583E-03	0.3663E-03	2.23
311.8	0.4236E-03	0.4172E-03	1.52
359.8	0.4431E-03	0.4343E-03	1.98
455.0	0.4695E-03	0.4626E-03	1.47
601.0	0.4736E-03	0.4961E-03	4.74
765.9	0.5319E-03	0.5247E-03	1.36
954.3	0.5486E-03	0.5499E-03	0.23
1174.6	0.5750E-03	0.5724E-03	0.45

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.9517E 01

76 ~~79~~ 78

C(2) = 0.1840E 00
C(3) = 0.4250E-01
C(4) = -0.3525E-02
C(5) = -0.5127E-04

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.8497E-05
STANDARD DEVIATION FOR ALL TIME = 0.8497E-05

....

D A T A   S E T   N U M B E R   3

NOTEBOOK NUMBER 52731 PAGE 18
MATERIAL:ETP COPPER WIRE COLD WORKED 10 PERCE
MATERIAL:NT
CREEP TEST
TEMPERATURE (IN DEGREES F):200.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 36.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.1486E-03	0.1483E-03	0.18
4.0	0.2222E-03	0.2238E-03	0.72
24.0	0.3972E-03	0.3913E-03	1.49
96.0	0.6250E-03	0.6267E-03	0.27
198.0	0.7750E-03	0.8107E-03	4.60
312.5	0.9750E-03	0.9556E-03	1.99
360.5	0.1033E-02	0.1006E-02	2.62
456.0	0.1106E-02	0.1095E-02	0.92
600.2	0.1194E-02	0.1209E-02	1.24
770.6	0.1315E-02	0.1322E-02	0.55
937.5	0.1419E-02	0.1418E-02	0.11
1175.9	0.1533E-02	0.1535E-02	0.13

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

77

78

79

C(1) = -0.8816E 01
C(2) = 0.2986E 00
C(3) = -0.5083E-02
C(4) = 0.2978E-02
C(5) = -0.2292E-03

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.1530E-04
STANDARD DEVIATION FOR ALL TIME = 0.1530E-04

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 17.50 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.2958E-03	0.2959E-03	0.04
4.0	0.4667E-03	0.4659E-03	0.17
24.0	0.8889E-03	0.8938E-03	0.55
96.0	0.1508E-02	0.1488E-02	1.36
198.0	0.1938E-02	0.1964E-02	1.39
312.5	0.2354E-02	0.2366E-02	0.50
360.5	0.2533E-02	0.2514E-02	0.76
456.0	0.2797E-02	0.2787E-02	0.36
600.2	0.3158E-02	0.3162E-02	0.13
770.6	0.3568E-02	0.3570E-02	0.06
937.5	0.3943E-02	0.3946E-02	0.07
1175.9	0.4458E-02	0.4456E-02	0.05

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.8125E 01
C(2) = 0.2869E 00
C(3) = 0.4011E-01
C(4) = -0.8922E-02
C(5) = 0.7332E-03

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.1229E-04
STANDARD DEVIATION FOR ALL TIME = 0.1229E-04

....

DATA SET NUMBER 4

7/8

8/

80

NOTEBOOK NUMBER 52731 PAGE 19
MATERIAL:OFHC COPPER WIRE WITH 60 OZ PER TON
MATERIAL:OF SILVER
CREEP TEST
TEMPERATURE (IN DEGREES F):200.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 36.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.1529E-04	0.1493E-04	2.34
4.0	0.1529E-04	0.1679E-04	9.86
24.0	0.4861E-04	0.3982E-04	18.08
96.0	0.6667E-04	0.7435E-04	11.52
198.0	0.7084E-04	0.9666E-04	36.46
312.0	0.1347E-03	0.1129E-03	16.18
360.5	0.1361E-03	0.1188E-03	12.75
456.0	0.1292E-03	0.1292E-03	0.06
600.2	0.1431E-03	0.1437E-03	0.48
770.6	0.1681E-03	0.1600E-03	4.80
937.5	0.1806E-03	0.1756E-03	2.72
1175.9	0.1806E-03	0.1982E-03	9.78

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.1111E 02
C(2) = -0.2999E 00
C(3) = 0.3620E 00
C(4) = -0.6650E-01
C(5) = 0.4049E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.1286E-04
STANDARD DEVIATION FOR ALL TIME = 0.1286E-04

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 24.20 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.1278E-03	0.1273E-03	0.36
4.0	0.1347E-03	0.1368E-03	1.51
24.0	0.2417E-03	0.2330E-03	3.59
96.0	0.3458E-03	0.3646E-03	5.42

198.0	0.4625E-03	0.4468E-03	3.39
312.0	0.4875E-03	0.5020E-03	2.97
360.5	0.5167E-03	0.5202E-03	0.68
456.0	0.5694E-03	0.5505E-03	3.32
600.2	0.5889E-03	0.5878E-03	0.19
770.6	0.6278E-03	0.6239E-03	0.62
937.5	0.6514E-03	0.6541E-03	0.42
1175.9	0.6861E-03	0.6920E-03	0.86

~~79~~ ~~80~~ 81

CONSTANTS FOR CURVE FITTING:

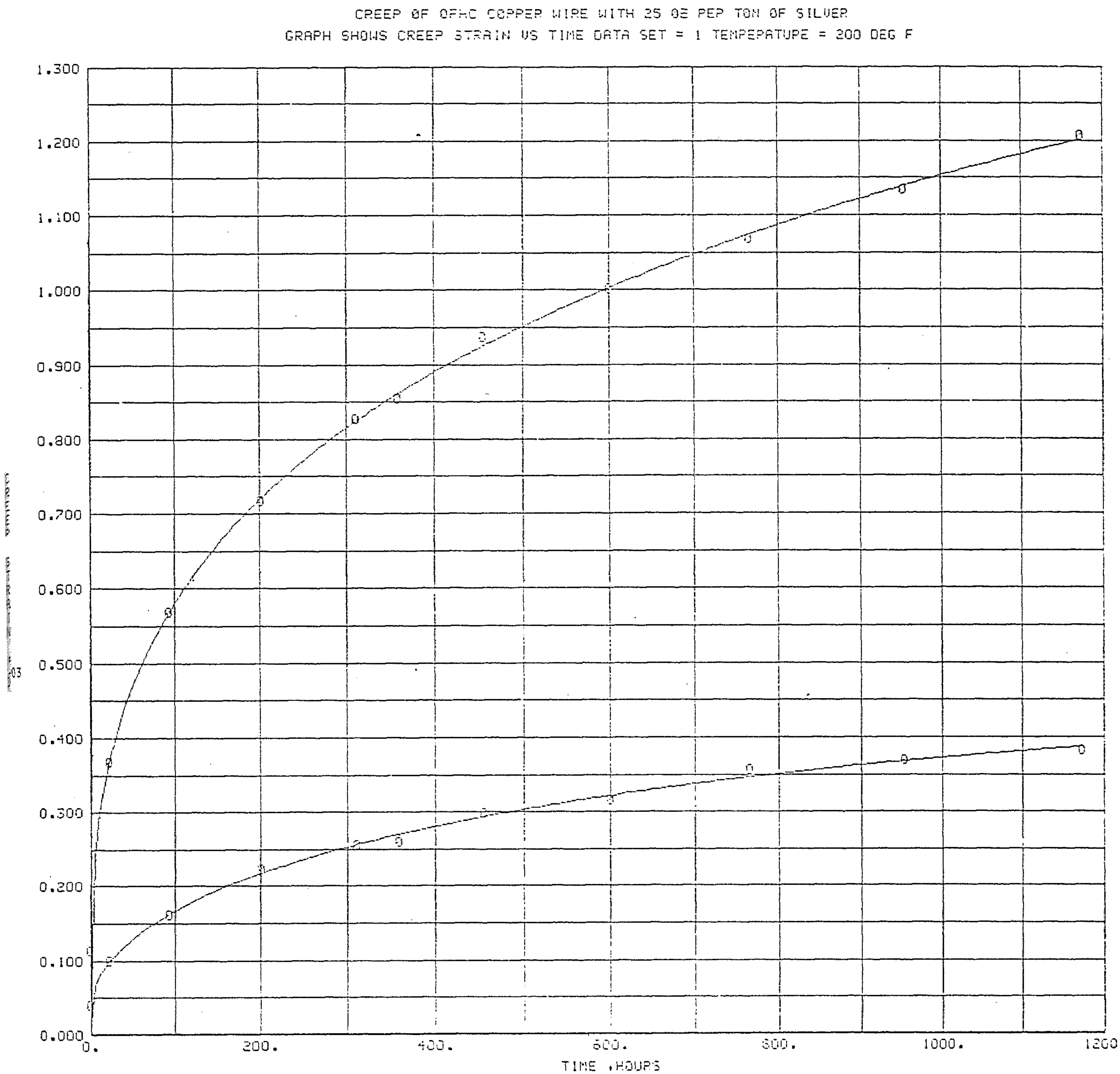
DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.8969E 01
C(2) = -0.1528E 00
C(3) = 0.1848E 00
C(4) = -0.2900E-01
C(5) = 0.1515E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.1046E-04
STANDARD DEVIATION FOR ALL TIME = 0.1046E-04

....

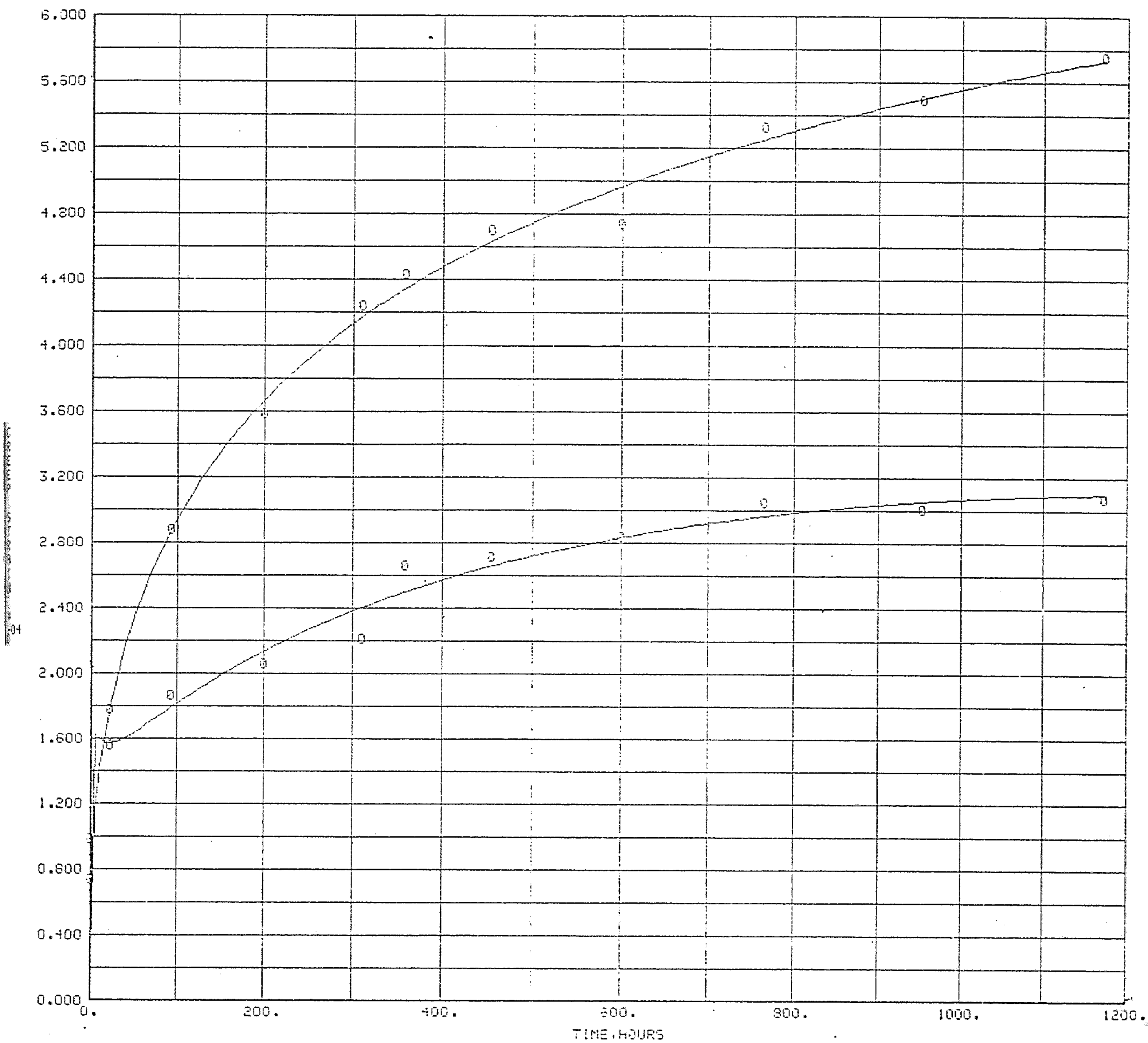
80 83 82



CREEP OF OFHC COPPER WIRE WITH 25 OZ PER TON OF SILVER
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 1 TEMPERATURE = 200 DEG F
1.300
1.200
1.100
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
0.
200.
400.
600.
800.
1000.
1200.
TIME ,HOURS

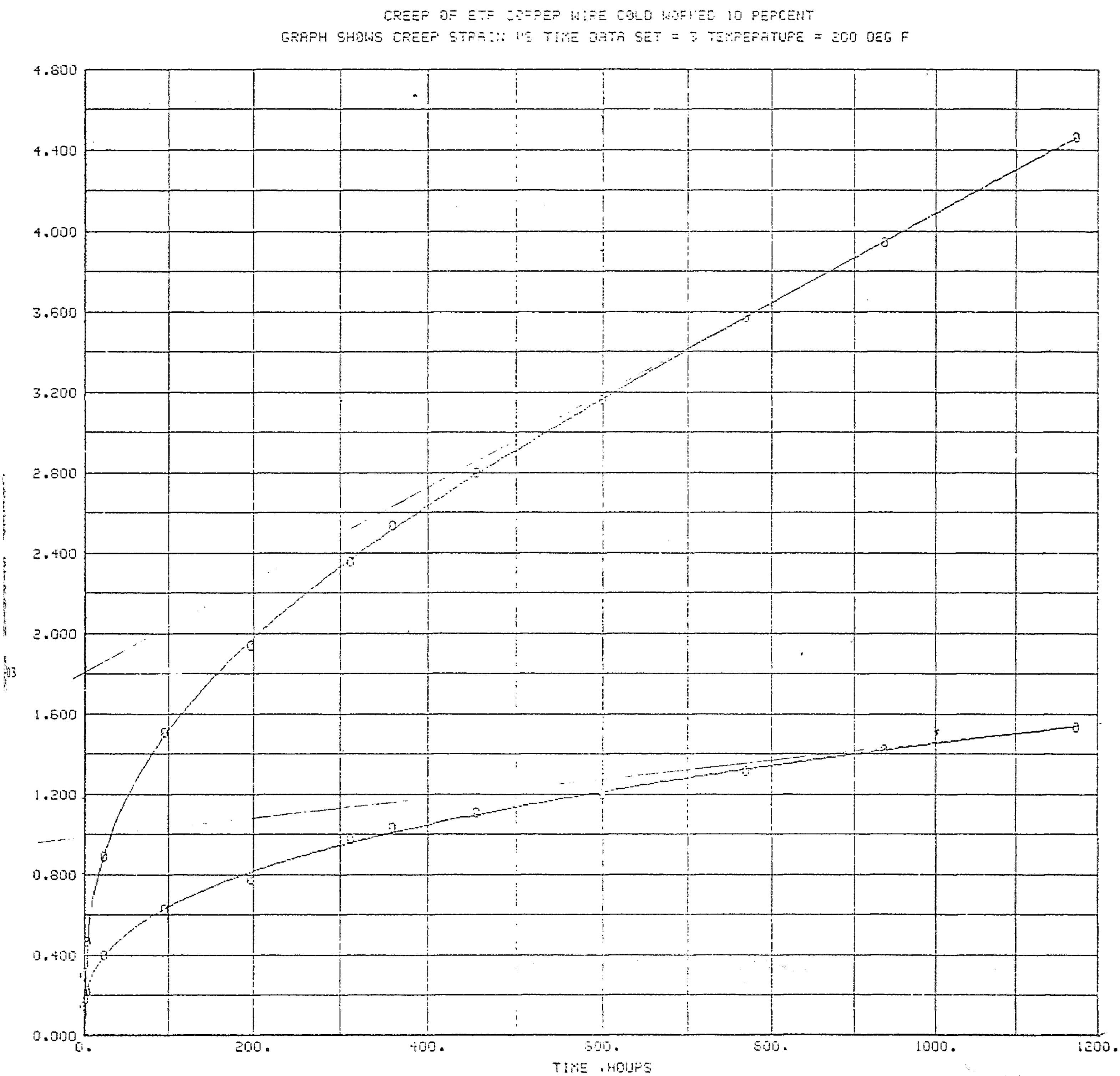
8~~4~~ 83

CREEP OF OFHC COPPER WIRE WITH 40 OZ PER TON OF SILVER
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 2 TEMPERATURE = 200 DEG F

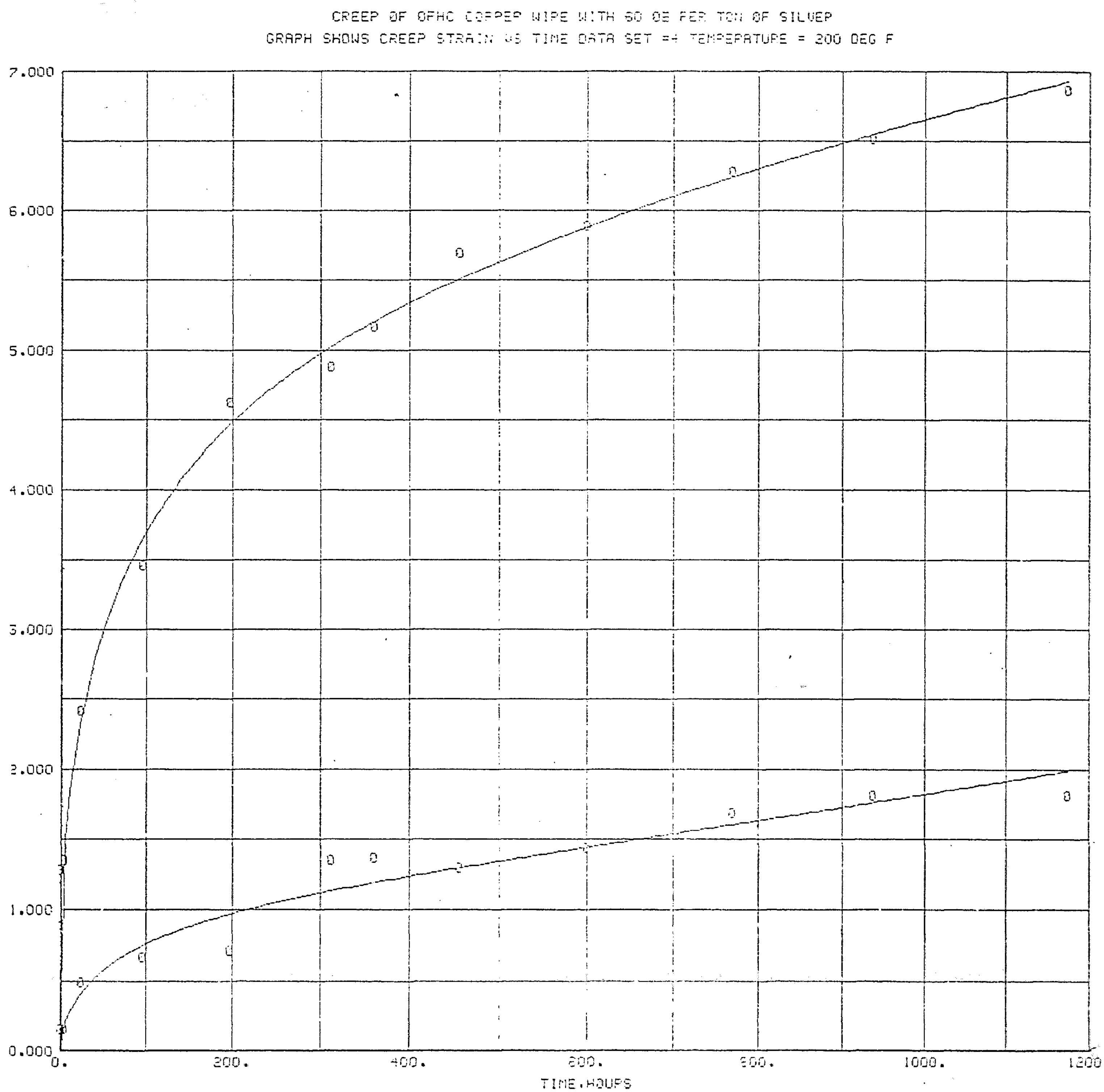


NUMB C0990 18.216 03/28
BOXM274.HAL
PAGE NO 03

(82) (85) (84)



83 85 85


CREEP OF OFHC COPPER WIRE WITH 60 OZ PER TON OF SILVER
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET =4 TEMPERATURE = 200 DEG F
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0.000
0.
200.
400.
600.
800.
1000.
1200.
TIME,HOURS

JOB #~~9~~ 8

~~96~~

86

```
1 1
2 4 1.0 0.01
CREEP OF HIGH PURITY(99.999+) PERCENT COPPER WIRE AT 73 F
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 1 TEMPERATURE = 73F
NONE
CREEP STRAIN
NONE
TIME,HOURS
HIGH PURITY(99.999+) COPPER WIRE AT 73 F
52731 7 73.0 0.0201 50.0 2 2 9
10.0 19.7
   0.0 50.0642 50.0870 50.1326 50.1318
   1.0 50.0653 50.0888 50.1382 50.1376
   4.0 50.0657 50.0905 50.1402 50.1405
  25.0 50.0679 50.0924 50.1465 50.1462
  98.0 50.0693 50.0944 50.1516 50.1501
 263.0 50.0719 50.0963 50.1564 50.1559
 533.0 50.0732 50.0967 50.1601 50.1612
 843.0 50.0740 50.0987 50.1646 50.1644
1007.0 ~~50.0823 50.0747 50.1394 50.1608~~
       50.0767 50.1008 50.1651 50.1676
```

Changed 4/4/72

------------------------------ 0550 CARDS READ ------------------------------

Ran OK.

SNUMB = C0880, ACTIVITY # = 01, REPORT CODE = 06, RECORD COUNT = 00092

Job #4

~~97~~
87

DATA SET NUMBER 1

NOTEBOOK NUMBER 52731 PAGE 7
MATERIAL:HIGH PURITY(99.999+) COPPER WIRE AT
MATERIAL:73 F
CREEP TEST
TEMPERATURE (IN DEGREES F): 73.0
SPECIMEN DIAMETER (IN INCHES): 0.0201
NOMINAL GAUGE LENGTH (INCHES): 50.0
MAX. NO. OF SPECIMENS AT EACH STRESS LEVEL : 2

****

STRESS LEVEL NO. 1 NOMINALSTRESS = 10.00 KPSI

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.2900E-04	0.2905E-04	0.17
4.0	0.5000E-04	0.4972E-04	0.56
25.0	0.9100E-04	0.9150E-04	0.55
98.0	0.1250E-03	0.1276E-03	2.07
263.0	0.1700E-03	0.1598E-03	6.03
533.0	0.1870E-03	0.1943E-03	3.88
843.0	0.2150E-03	0.2282E-03	6.15
1007.0	0.2600E-03	0.2454E-03	5.60

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

C(1) = -0.1045E 02
C(2) = 0.3733E 00
C(3) = 0.2819E-01
C(4) = -0.1470E-01
C(5) = 0.1340E-02

STANDARD DEVIATION FOR TIME .GE. 1.0 HRS. = 0.8303E-05
STANDARD DEVIATION FOR ALL TIME = 0.8303E-05

....

STRESS LEVEL NO. 2 NOMINALSTRESS = 19.70 KPSI

88

TIME (HRS.)	CREEP STRAIN	BEST FIT	PERCENT ERROR
1.0	0.1140E-03	0.1139E-03	0.11
4.0	0.1630E-03	0.1638E-03	0.49
25.0	0.2830E-03	0.2791E-03	1.38
98.0	0.3730E-03	0.3818E-03	2.35
263.0	0.4790E-03	0.4713E-03	1.61
533.0	0.5690E-03	0.5658E-03	0.56
843.0	0.6460E-03	0.6589E-03	2.00
1007.0	0.7140E-03	0.7062E-03	1.10

CONSTANTS FOR CURVE FITTING:

DATA FIT TO LOGARITHMIC POWER EXPANSION

```
C(1) =  -0.9080E 01
C(2) =   0.1891E 00
C(3) =   0.7899E-01
C(4) =  -0.2117E-01
C(5) =   0.1636E-02
```

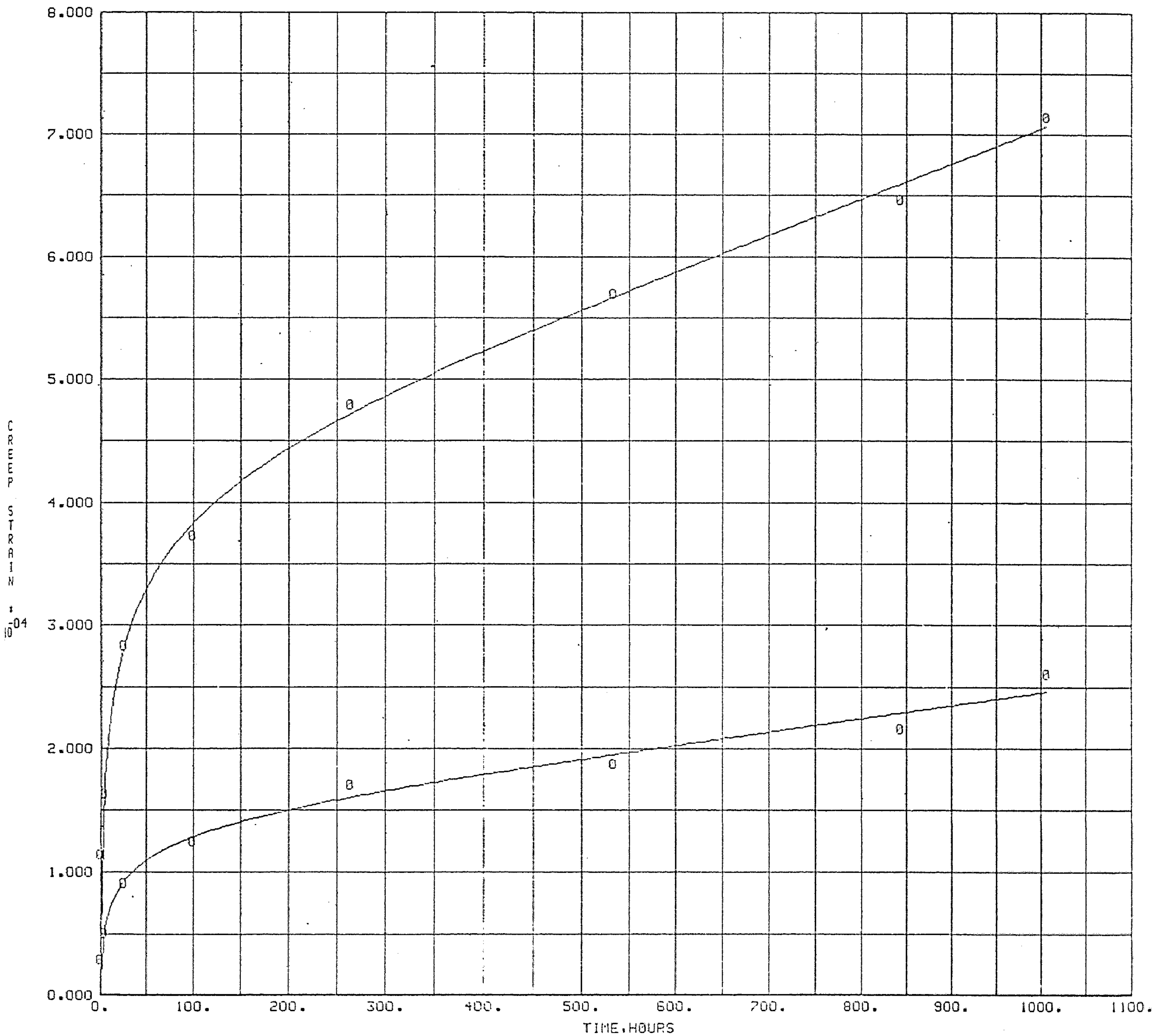
STANDARD DEVIATION FOR TIME .GE.   1.0 HRS. =   0.6983E-05
STANDARD DEVIATION FOR ALL TIME =   0.6983E-05

....

ONLY STARE OUTPUT CALLED FOR

~~99~~
89

CREEP OF HIGH PURITY(99.999+) PERCENT COPPER WIRE AT 73 F
GRAPH SHOWS CREEP STRAIN VS TIME DATA SET = 1 TEMPERATURE = 73F



Job # 9

p. 90

```
2 1
STRESS RELAXATION OF ETP COPPER WIRE AT 200 DEG F
TIME HOURS
REMAINING STRESS PERCENT OF INITIAL
TIME HOURS
STRESS RELAXATION OF ETP COPPER WIRE AT 200 DEG F
*=EXPERIMENTAL DATA CONTINUOUS CURVE =BEST FIT DATA SET =1
52731 24 0.0201 200.0 8 2 2
    0.0 84.8 84.8 62.5 64.6
    1.0 79.8 78.6 60.0 61.4
    4.0 77.4 76.4 59.0 60.1
   28.1 71.3 70.4 56.3 56.6
  124.8 64.5 64.0 53.6 52.3
  289.1 60.6 60.2 50.8 49.4
  461.5 57.2 56.9 49.5 47.6
  702.8 55.7 55.2 48.2 45.8
17.5 10.0 85.9 64.9
STRESS RELAXATION OF ETP COPPER WIRE WITH 25 OZ PER TON OF AG AT 200 F
TIME HOURS
REMAINING STRESS PERCENT OF INITIAL
TIME HOURS
STRESS RELAXATION OF ETP COPPER WIRE WITH 25 OZ PER TON OF AG
*=DATA CONTINUOUS CURVE =BEST FIT DATA SET = 2 TEMP =200F
52731 24 0.0201 200.0 8 2 2
    0.0 91.8 93.5 61.2 63.9
    1.0 88.5 90.1 60.3 62.0
    4.0 86.5 88.2 60.0 61.4
   28.1 83.6 84.6 59.5 60.0
  124.8 79.0 80.4 57.3 57.7
  289.1 76.1 77.3 55.5 55.5
  461.5 74.2 75.3 54.2 54.5
  702.8 72.3 73.6 52.9 52.8
20.7 10.0 93.4 64.9

------------------------------- 0348 CARDS READ -------------------------------
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RAN

3/28/72

SNUMB = C0029, ACTIVITY # = 01, REPORT CODE = 06, RECORD COUNT = 00171

ONLY STARE OUTPUT CALLED FOR

91

D A T A   S E T   N U M B E R   1

NOTEBOOK NUMBER 52731 PAGE 24
MATERIAL:STRESS RELAXATION OF ETP COPPER WIRE
STRESS RELAXATION TEST
TEMPERATURE (DEGREES F):200.0
SPECIMEN DIAMETER (INCHES): 0.0201
NO. OF SPECIMEN AT EACH STRESS LEVEL: 2
FREQUENCY SQUARED = 421.65*STRESS

WHEN DATA IS PLOTTED LINEARLY, A CURVE IS FIT
ACCORDING TO THE EQN: Y=C1/(X**A2)+C2+C3*(X**A2)

WHEN DATA IS PLOTTED LOGARITHMICALLY, A CURVE IS FIT
ACCORDING TO THE EQN: Y=C1+C2*ALOG10(X)

****

STRESS LEVEL NO. 1 NOMINAL STRESS = 17.50KPSI

TIME HRS.	LOG OF TIME	RATIO	STRESS REMAINING (KPSI)
0.	.....	100.0	17.50
1.0	0.	87.2	15.27
4.0	0.6	82.2	14.39
26.1	1.4	69.8	12.22
124.8	2.1	57.4	10.05
289.1	2.5	50.7	8.88
461.5	2.7	45.3	7.92
702.8	2.8	42.8	7.48

CONSTANTS FOR EQN. FITTING DATA PLOTTED LINEARLY:
A2= 0.07 C1= -60.23 C2= 268.60 C3= -120.48

DATA FOR EQN. FITTING DATA PLOTTED LOGARITHMICALLY:
C1= 99.63 C2= -20.10

AT T=40 YEARS, RATIO IS NEGATIVE.

STRESS LEVEL NO. 2 NOMINAL STRESS = 10.00KPSI

TIME HRS.	LOG OF TIME	RATIO	STRESS REMAINING (KPSI)
0.	.....	100.0	10.00
1.0	0.	91.2	9.12
4.0	0.6	87.8	8.78
28.1	1.4	78.9	7.89
124.8	2.1	69.4	6.94
289.1	2.5	62.1	6.21
461.5	2.7	58.4	5.84
702.8	2.8	54.7	5.47

92

CONSTANTS FOR EQN. FITTING DATA PLOTTED LINEARLY:
A2= 0.04 C1= -274.18 C2= 679.60 C3= -314.15

DATA FOR EQN. FITTING DATA PLOTTED LOGARITHMICALLY:
C1= 110.30 C2= -19.52

AT T=40 YEARS, RATIO = 2.1 AND STRESS REMAINING = 0.21

D A T A S E T N U M B E R 2

NOTEBOOK NUMBER 52731 PAGE 24
MATERIAL:STRESS RELAXATION OF ETP COPPER WIRE 12507 AG.
STRESS RELAXATION TEST
TEMPERATURE (DEGREES F):200.0
SPECIMEN DIAMETER (INCHES): 0.0201
NO. OF SPECIMEN AT EACH STRESS LEVEL: 2
FREQUENCY SQUARED = 421.43*STRESS

WHEN DATA IS PLOTTED LINEARLY, A CURVE IS FIT
ACCORDING TO THE EQN: Y=C1/(X**A2)+C2+C3*(X**A2)

WHEN DATA IS PLOTTED LOGARITHMICALLY, A CURVE IS FIT
ACCORDING TO THE EQN: Y=C1+C2*ALOG10(X)

****

STRESS LEVEL NO. 1 NOMINAL STRESS = 20.70KPSI

TIME HRS.	LOG OF TIME	RATIO	STRESS REMAINING (KPSI)
0.	.....	100.0	20.70
1.0	0.	92.9	19.23
4.0	0.6	88.9	18.40
28.1	1.4	81.8	16.93
124.8	2.1	74.0	15.32
289.1	2.5	68.5	14.19
461.5	2.7	65.1	13.47
702.8	2.8	62.0	12.83

CONSTANTS FOR EQN. FITTING DATA PLOTTED LINEARLY:
A2= 0.04 C1= -266.91 C2= 673.87 C3= -314.31

DATA FOR EQN. FITTING DATA PLOTTED LOGARITHMICALLY:
C1= 107.61 C2= -15.97

AT T=40 YEARS, RATIO = 19.0 AND STRESS REMAINING = 3.94

STRESS LEVEL NO. 2 NOMINAL STRESS = 10.00KPSI

TIME HRS.	LOG OF TIME	RATIO	STRESS REMAINING (KPSI)
0.	.....	100.0	10.00
1.0	0.	95.5	9.55
4.0	0.6	94.1	9.41
28.1	1.4	91.2	9.12
124.8	2.1	84.5	8.45
289.1	2.5	78.7	7.87
461.5	2.7	75.5	7.55
702.8	2.8	71.4	7.14

CONSTANTS FOR EQN. FITTING DATA PLOTTED LINEARLY:
A2= 0.01 C1=-3734.43 C2= 7472.57 C3=-3643.26

DATA FOR EQN. FITTING DATA PLOTTED LOGARITHMICALLY:
C1= 120.63 C2= -17.14

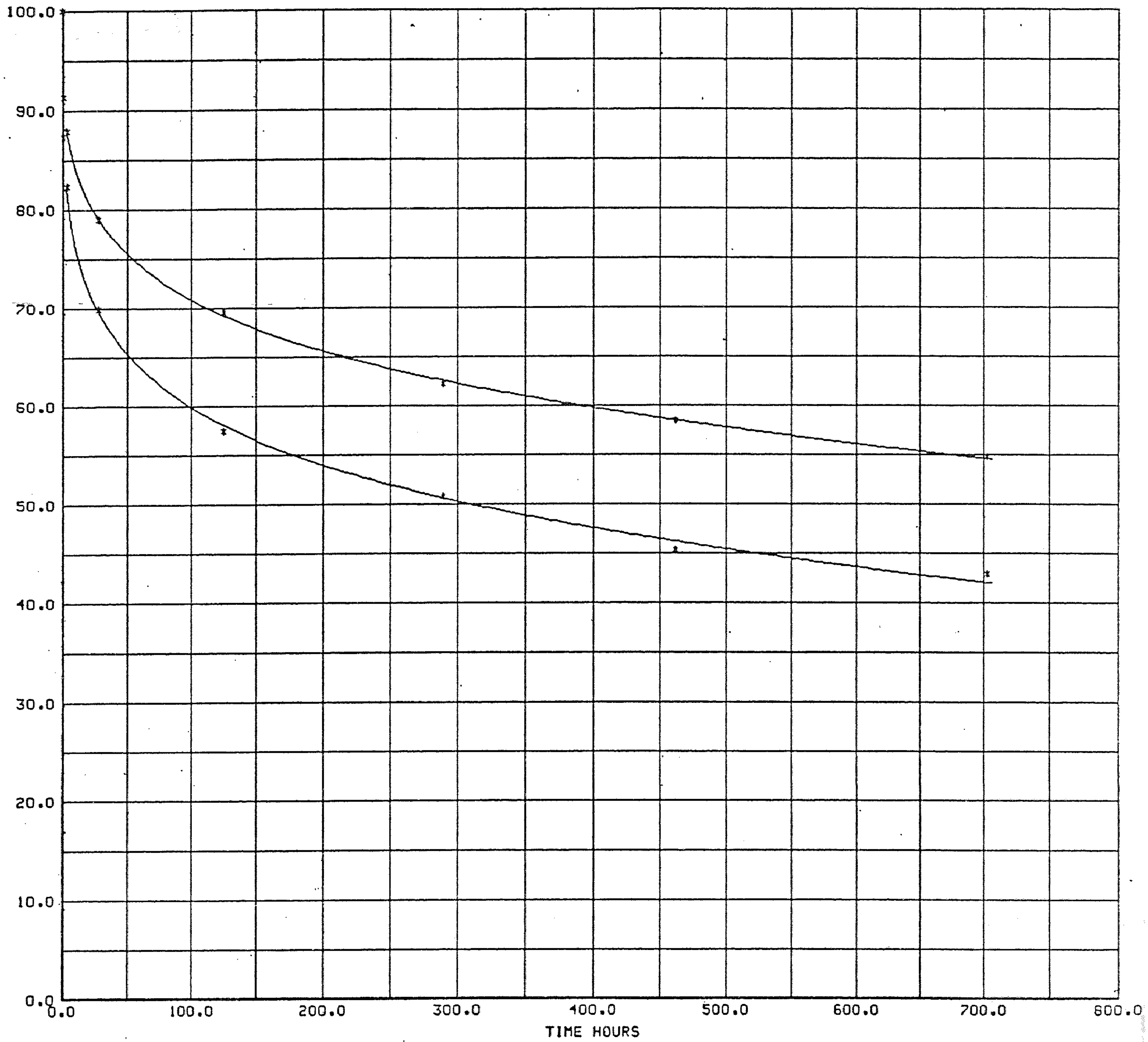
AT T=40 YEARS, RATIO = 25.6 AND STRESS REMAINING = 2.56

C0029 17.344 03/28
1274.HAL
NO 01

(94)

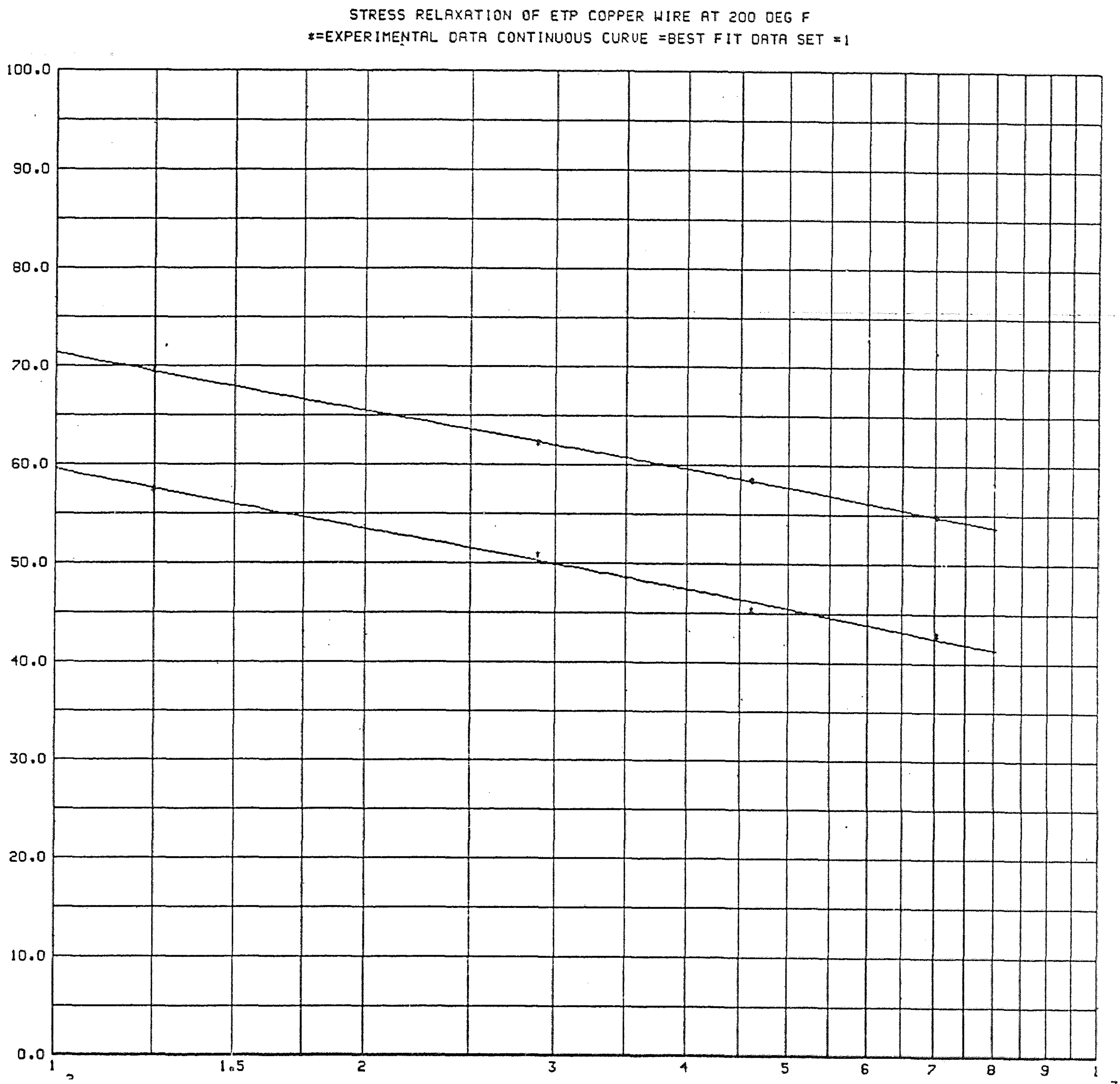
STRESS RELAXATION OF ETP COPPER WIRE AT 200 DEG F

*=EXPERIMENTAL DATA CONTINUOUS CURVE =BEST FIT DATA SET =1

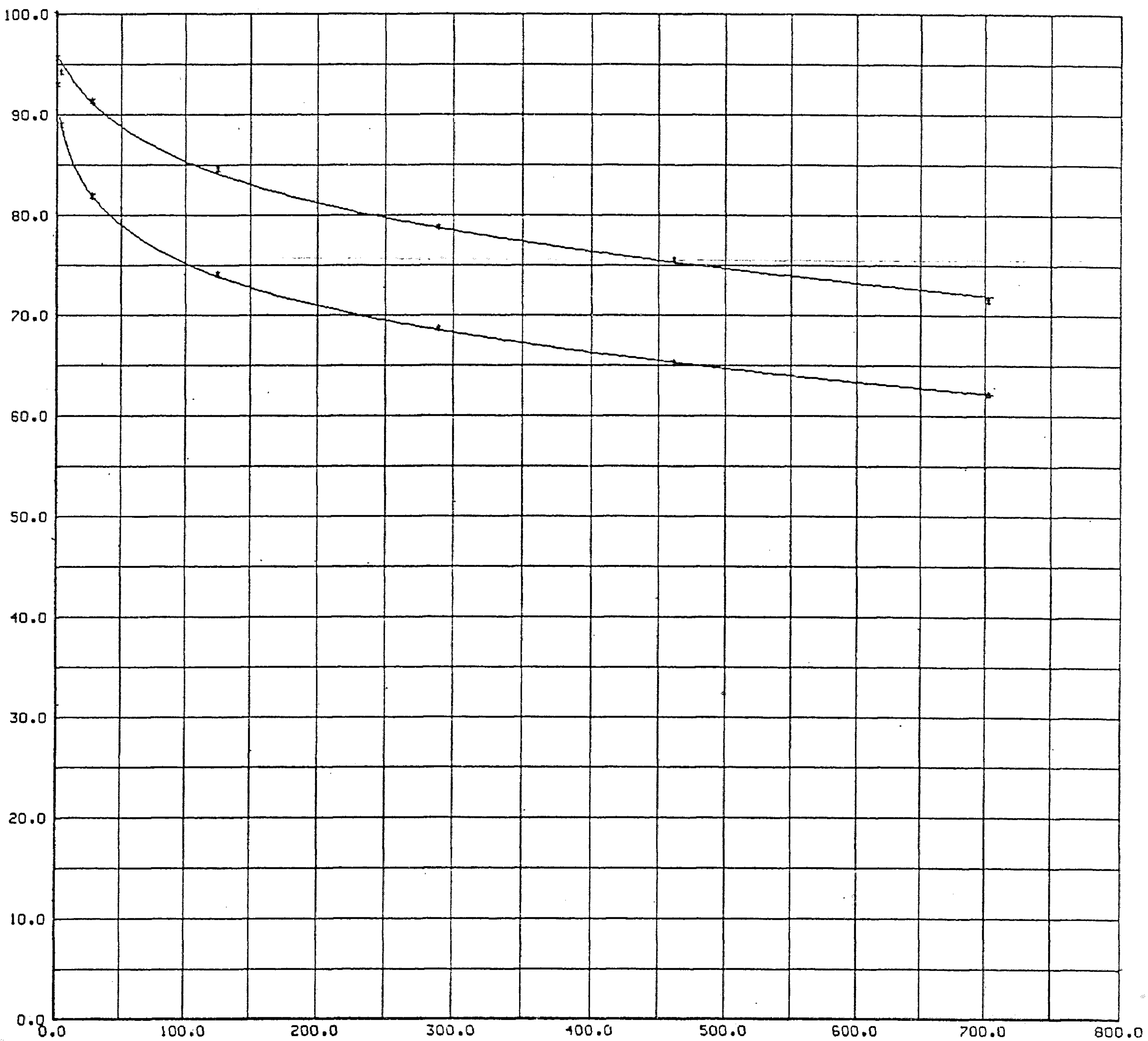


LMB C0029 17.344 03/28
MXM274.HAL
PGE NO 02

(95)



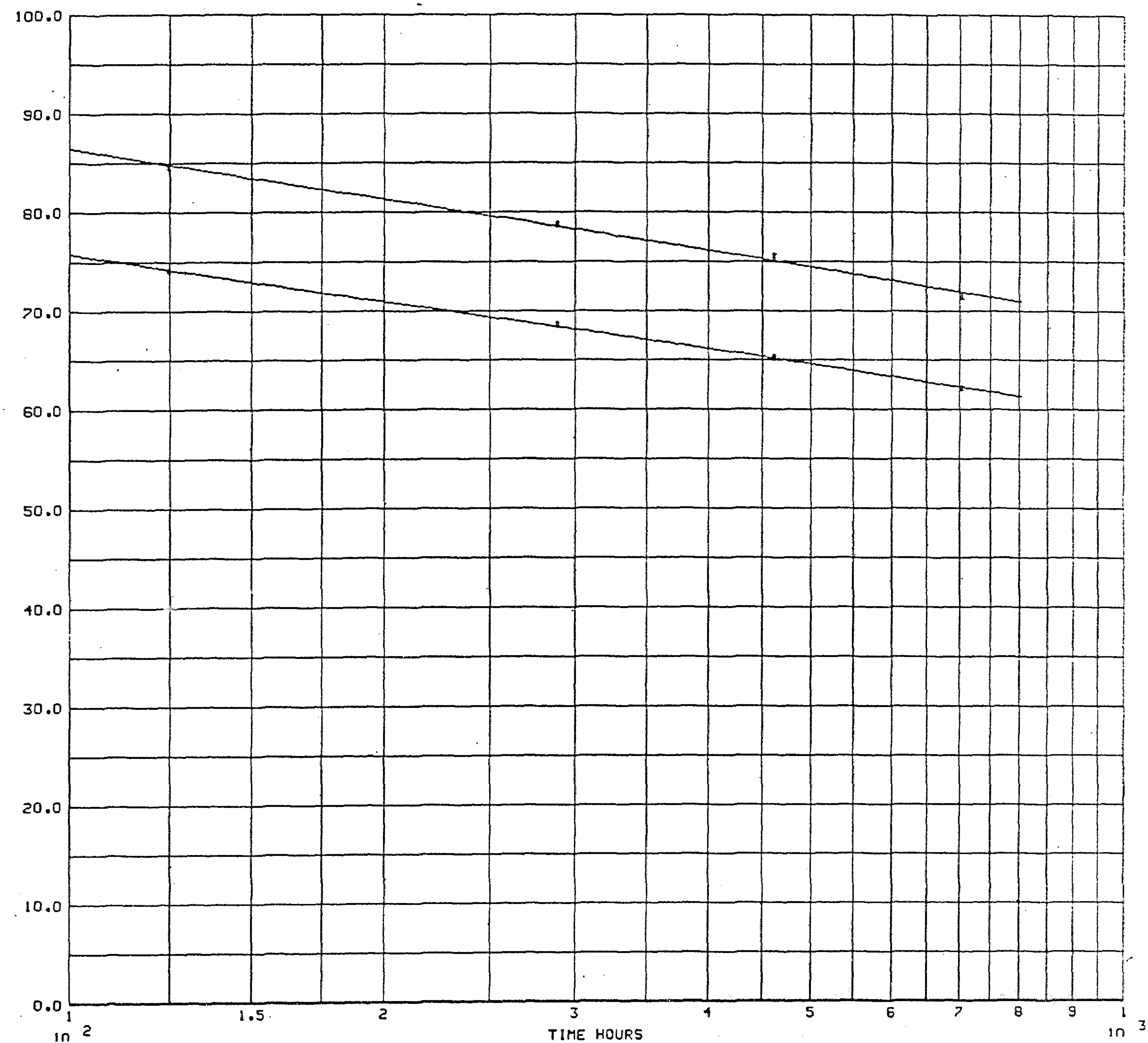
STRESS RELAXATION OF ETP COPPER WIRE WITH 25 OZ PER TON OF AG
*=DATA CONTINUOUS CURVE =BEST FIT DATA SET = 2 TEMP =200F



B C0029 17.344 03/28
M274.HAL
E NO 04

(97)

STRESS RELAXATION OF ETP COPPER WIRE WITH 25 OZ PER TON OF AG
*=DATA CONTINUOUS CURVE =BEST FIT DATA SET = 2 TEMP =200F



```
4 1
OFHC CU AT 200 F
TIME HOURS
REMAINING STRESS PERCENT OF INITIAL
TIME HOURS
OFHC COPPER
*=TEST DATA DATA SET =1
52731 24 0.0201 200.0 8 2 2
    0.0 90.0 93.2 63.4 60.6
    1.0 85.1 89.3 60.8 56.8
    4.0 82.7 87.3 60.6 56.3
   28.1 79.0 83.1 60.5 56.3
  124.8 74.1 77.5 55.0 50.7
  289.1 70.2 74.1 54.0 49.6
  461.5 68.9 72.1 52.3 49.5
  702.8 66.4 69.6 49.4 45.5
20.6 10.0 93.2 64.9
OFHC CU WITH 25 OZ AG PER TON
TIME HOURS
REMAINING STRESS PERCENT OF INITIAL
TIME HOURS
OFHC CU WITH 25 OZ AG PER TON
*=EXPERIMENTAL DATA CONTINUOUS CURVE =BEST FIT DATA SET =2 TEMP =200F
52731 24 0.0201 200.0 8 2 2
    0.0 95.9 93.3 61.7 62.0
    1.0 90.3 89.3 60.9 61.3
    4.0 89.3 87.6 60.9 61.3
   28.1 85.0 83.5 59.4 60.3
  124.8 80.0 79.0 57.1 58.4
  289.1 78.4 78.4 57.0 58.3
  461.5 76.4 75.5 55.7 57.1
  702.8 73.3 73.4 54.8 55.3
22.1 10.0 96.5 64.9
OFHC CU WITH 40 OZ AG PER TON
TIME HOURS
REMAINING STRESS PERCENT OF INITIAL
TIME HOURS
OFHC CU WITH 40 OZ AG PER TON
*=EXPERIMENTAL DATA CONTINUOUS CURVE =BEST FIT DATA SET =3 TEMP =200F
52731 24 0.0201 200.0 8 2 2
    0.0 89.1 88.7 63.8 65.3
    1.0 87.4 87.5 63.2 65.0
    4.0 86.4 86.7 62.5 64.8
   28.1 85.1 84.7 62.3 64.8
  124.8 81.7 82.1 60.8 63.4
  289.1 81.4 81.8 60.8 63.0
  461.5 79.8 80.2 60.5 63.0
  702.8 78.2 78.7 59.4 61.8
18.7 10.0 98.8 64.9
OFHC CU WITH 60 OZ PER TON AG
TIME, HOURS
REMAINING STRESS, PERCENT OF INITIAL
TIME HOURS
OFHC CU WITH 60 OZ PER TON OF AG
*=EXPERIMENTAL DATA CONTINUOUS CURVE =BEST FIT DATA SET =4 TEMP =200F
52731 24 0.0201 200.0 8 2 2
    0.0 99.7 99.9 63.5 63.5
    1.0 99.0 99.1 62.4 62.4
    4.0 98.1 98.1 62.4 62.4
```

JOB (10)

(98)

28.1	96.9	96.8	62.4	62.3
124.8	94.6	93.9	62.2	62.2
289.8	93.8	93.0	61.5	61.7
461.5	93.0	92.3	61.5	61.6
702.8	91.9	91.2	60.4	60.4
24.2	10.0	100.9	64.9	

99

SNUMB = C0101, ACTIVITY # = 01, REPORT CODE = 06, RECORD COUNT = 00341

ONLY STARE OUTPUT CALLED FOR

100

D A T A S E T N U M B E R 1

NOTEBOOK NUMBER 52731 PAGE 24
MATERIAL:OFHC CU AT 200 F
STRESS RELAXATION TEST
TEMPERATURE (DEGREES F):200.0
SPECIMEN DIAMETER (INCHES): 0.0201
NO. OF SPECIMEN AT EACH STRESS LEVEL: 2
FREQUENCY SQUARED = 421.66*STRESS

WHEN DATA IS PLOTTED LINEARLY, A CURVE IS FIT
ACCORDING TO THE EQN: Y=C1/(X**A2)+C2+C3*(X**A2)

WHEN DATA IS PLOTTED LOGARITHMICALLY, A CURVE IS FIT
ACCORDING TO THE EQN: Y=C1+C2*ALOG10(X)

****

STRESS LEVEL NO. 1 NOMINAL STRESS = 20.60KPSI

TIME HRS.	LOG OF TIME	RATIO	STRESS REMAINING (KPSI)
0.	.....	100.0	20.60
1.0	0.	90.6	18.67
4.0	0.6	86.1	17.75
28.1	1.4	78.3	16.13
124.8	2.1	68.5	14.11
289.1	2.5	62.1	12.79
461.5	2.7	59.2	12.21
702.8	2.8	55.1	11.36

CONSTANTS FOR EQN. FITTING DATA PLOTTED LINEARLY:
A2= 0.04 C1= -221.31 C2= 582.55 C3= -270.74

DATA FOR EQN. FITTING DATA PLOTTED LOGARITHMICALLY:
C1= 105.05 C2= -17.41

AT T=40 YEARS, RATIO = 8.5 AND STRESS REMAINING = 1.76

STRESS LEVEL NO. 2 NOMINAL STRESS = 10.00KPSI

TIME HRS.	LOG OF TIME	RATIO	STRESS REMAINING (KPSI)
0.	.....	100.0	10.00
1.0	0.	90.0	9.00
4.0	0.6	89.0	8.90
28.1	1.4	88.8	8.88
124.8	2.1	72.7	7.27
289.1	2.5	69.9	6.99
461.5	2.7	67.4	6.74
702.8	2.8	58.6	5.86

107

CONSTANTS FOR EQN. FITTING DATA PLOTTED LINEARLY:
A2= 0.00 C1= 9006.26 C2=16503.11 C3= 7592.55

DATA FOR EQN. FITTING DATA PLOTTED LOGARITHMICALLY:
C1= 109.92 C2= -16.98

AT T=40 YEARS, RATIO = 15.8 AND STRESS REMAINING = 1.58

D A T A S E T N U M B E R 2

NOTEBOOK NUMBER 52731 PAGE 24
MATERIAL:OFHC CU WITH 25 OZ AG PER TON
STRESS RELAXATION TEST
TEMPERATURE (DEGREES F):200.0
SPECIMEN DIAMETER (INCHES): 0.0201
NO. OF SPECIMEN AT EACH STRESS LEVEL: 2
FREQUENCY SQUARED = 421.37*STRESS

WHEN DATA IS PLOTTED LINEARLY, A CURVE IS FIT
ACCORDING TO THE EQN: Y=C1/(X**A2)+C2+C3*(X**A2)

WHEN DATA IS PLOTTED LOGARITHMICALLY, A CURVE IS FIT
ACCORDING TO THE EQN: Y=C1+C2*ALOG10(X)

****

STRESS LEVEL NO. 1 NOMINAL STRESS = 22.10KPSI

TIME HRS.	LOG OF TIME	RATIO	STRESS REMAINING (KPSI)
0.	.....	100.0	22.10
1.0	0.	90.1	19.91
4.0	0.6	87.4	19.32
28.1	1.4	79.3	17.53
124.8	2.1	70.6	15.61
289.1	2.5	68.7	15.18
461.5	2.7	64.4	14.24
702.8	2.8	60.1	13.28

(102)

CONSTANTS FOR EQN. FITTING DATA PLOTTED LINEARLY:
A2= 0.04 C1= -220.76 C2= 582.51 C3= -271.43

DATA FOR EQN. FITTING DATA PLOTTED LOGARITHMICALLY:
C1= 100.50 C2= -13.72

AT T=40 YEARS, RATIO = 24.4 AND STRESS REMAINING = 5.40

STRESS LEVEL NO. 2 NOMINAL STRESS = 10.00KPSI

TIME HRS.	LOG OF TIME	RATIO	STRESS REMAINING (KPSI)
0.	.....	100.0	10.00
1.0	0.	97.6	9.76
4.0	0.6	97.6	9.76
28.1	1.4	93.6	9.36
124.8	2.1	87.2	8.72
289.1	2.5	86.9	8.69
461.5	2.7	83.2	8.32
702.8	2.8	79.2	7.92

CONSTANTS FOR EQN. FITTING DATA PLOTTED LINEARLY:
A2= 0.01 C1=-2633.91 C2= 5347.41 C3=-2615.73

DATA FOR EQN. FITTING DATA PLOTTED LOGARITHMICALLY:
C1= 110.08 C2= -10.31

AT T=40 YEARS, RATIO = 52.9 AND STRESS REMAINING = 5.29

D A T A S E T N U M B E R 3

NOTEBOOK NUMBER 52731 PAGE 24
MATERIAL:OFHC CU WITH 40 OZ AG PER TON
STRESS RELAXATION TEST
TEMPERATURE (DEGREES F):200.0
SPECIMEN DIAMETER (INCHES): 0.0201
NO. OF SPECIMEN AT EACH STRESS LEVEL: 2
FREQUENCY SQUARED = 421.68*STRESS

103

WHEN DATA IS PLOTTED LINEARLY, A CURVE IS FIT
ACCORDING TO THE EQN: Y=C1/(X**A2)+C2+C3*(X**A2)

WHEN DATA IS PLOTTED LOGARITHMICALLY, A CURVE IS FIT
ACCORDING TO THE EQN: Y=C1+C2*ALOG10(X)

****

STRESS LEVEL NO. 1 NOMINAL STRESS = 18.70KPSI

TIME HRS.	LOG OF TIME	RATIO	STRESS REMAINING (KPSI)
0.	.....	100.0	18.70
1.0	0.	96.8	18.09
4.0	0.6	94.8	17.72
28.1	1.4	91.2	17.06
124.8	2.1	84.9	15.87
289.1	2.5	84.3	15.76
461.5	2.7	81.0	15.14
702.8	2.8	77.9	14.56

CONSTANTS FOR EQN. FITTING DATA PLOTTED LINEARLY:
A2= 0.02 C1= -984.50 C2= 2100.65 C3=-1019.57

DATA FOR EQN. FITTING DATA PLOTTED LOGARITHMICALLY:
C1= 105.05 C2= -9.16

AT T=40 YEARS, RATIO = 54.3 AND STRESS REMAINING = 10.15

STRESS LEVEL NO. 2 NOMINAL STRESS = 10.00KPSI

TIME HRS.	LOG OF TIME	RATIO	STRESS REMAINING (KPSI)
0.	.....	100.0	10.00
1.0	0.	98.6	9.86
4.0	0.6	97.2	9.72
28.1	1.4	97.0	9.70
124.8	2.1	92.6	9.26
289.1	2.5	92.0	9.20
461.5	2.7	91.5	9.15
702.8	2.8	88.2	8.82

CONSTANTS FOR EQN. FITTING DATA PLOTTED LINEARLY:
A2= 0.00 C1=-1022.72 C2= 2399.14 C3=-1277.02

104

DATA FOR EQN. FITTING DATA PLOTTED LOGARITHMICALLY:
C1= 103.85 C2= -5.08

AT T=40 YEARS, RATIO = 75.7 AND STRESS REMAINING = 7.57

D A T A S E T N U M B E R 4

NOTEBOOK NUMBER 52731 PAGE 24
MATERIAL:OFHC CU WITH 60 OZ PER TON AG
STRESS RELAXATION TEST
TEMPERATURE (DEGREES F):200.0
SPECIMEN DIAMETER (INCHES): 0.0201
NO. OF SPECIMEN AT EACH STRESS LEVEL: 2
FREQUENCY SQUARED = 420.69*STRESS

WHEN DATA IS PLOTTED LINEARLY, A CURVE IS FIT
ACCORDING TO THE EQN: Y=C1/(X**A2)+C2+C3*(X**A2)

WHEN DATA IS PLOTTED LOGARITHMICALLY, A CURVE IS FIT
ACCORDING TO THE EQN: Y=C1+C2*ALOG10(X)

****

STRESS LEVEL NO. 1 NOMINAL STRESS = 24.20KPSI

TIME HRS.	LOG OF TIME	RATIO	STRESS REMAINING (KPSI)
0.	.....	100.0	24.20
1.0	0.	98.5	23.84
4.0	0.6	96.6	23.38
28.1	1.4	94.2	22.79
124.8	2.1	89.2	21.58
289.8	2.5	87.6	21.20
461.5	2.7	86.2	20.86
702.8	2.8	84.2	20.36

CONSTANTS FOR EQN. FITTING DATA PLOTTED LINEARLY:
A2= 0.01 C1=-1092.77 C2= 2343.93 C3=-1152.70

105

DATA FOR EQN. FITTING DATA PLOTTED LOGARITHMICALLY:
C1= 103.09 C2= -6.48

AT T=40 YEARS, RATIO = 67.2 AND STRESS REMAINING = 16.25

STRESS LEVEL NO. 2 NOMINAL STRESS = 10.00KPSI

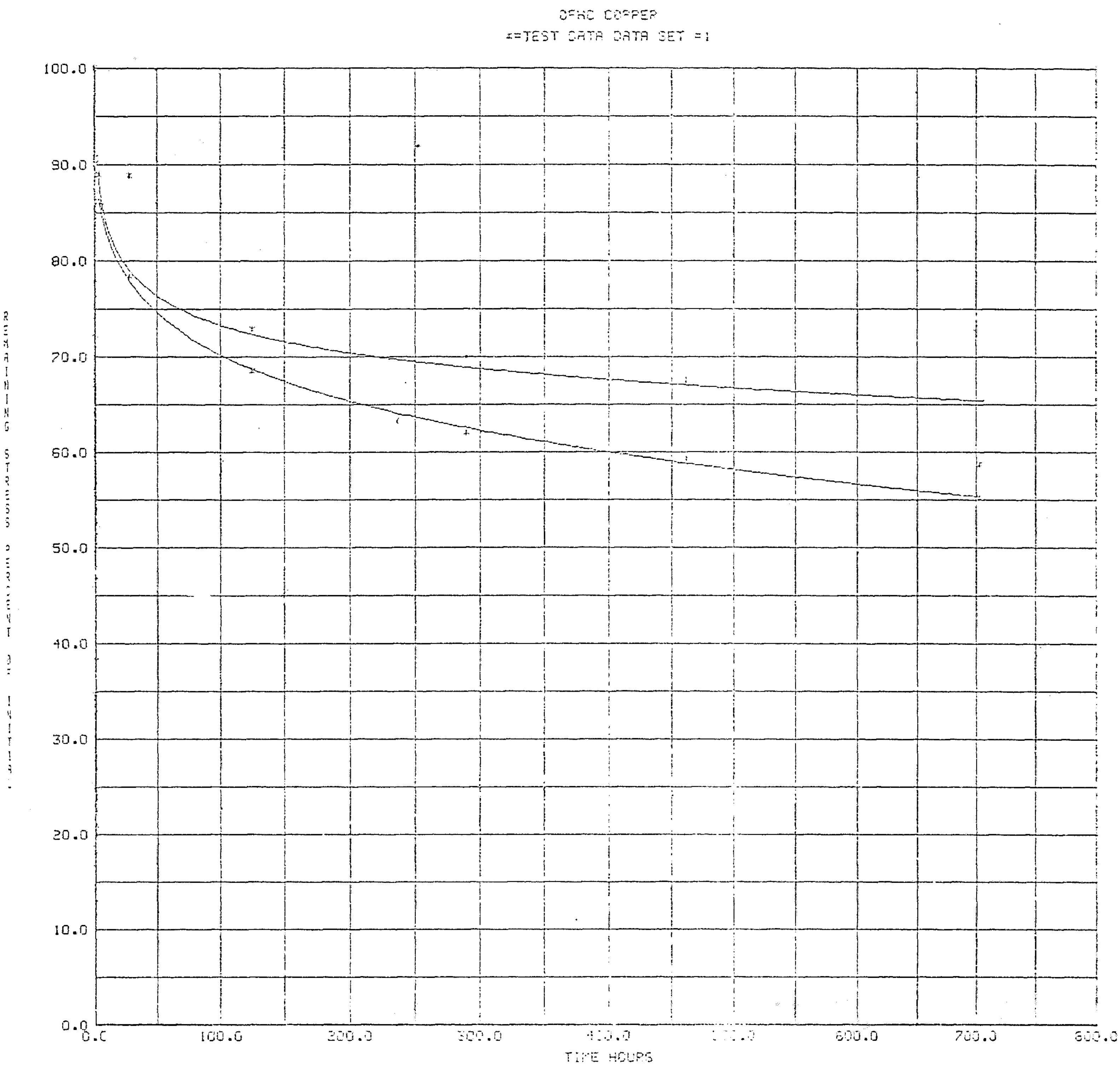
TIME HRS.	LOG OF TIME	RATIO	STRESS REMAINING (KPSI)
0.	.....	100.0	10.00
1.0	0.	96.6	9.66
4.0	0.6	96.6	9.66
28.1	1.4	96.4	9.64
124.8	2.1	95.9	9.59
289.8	2.5	94.1	9.41
461.5	2.7	94.0	9.40
702.8	2.8	90.5	9.05

CONSTANTS FOR EQN. FITTING DATA PLOTTED LINEARLY:
A2= 0.00 C1= 189.05 C2= 1071.66 C3=-1163.13

DATA FOR EQN. FITTING DATA PLOTTED LOGARITHMICALLY:
C1= 109.79 C2= -6.42

AT T=40 YEARS, RATIO = 74.2 AND STRESS REMAINING = 7.42

(106)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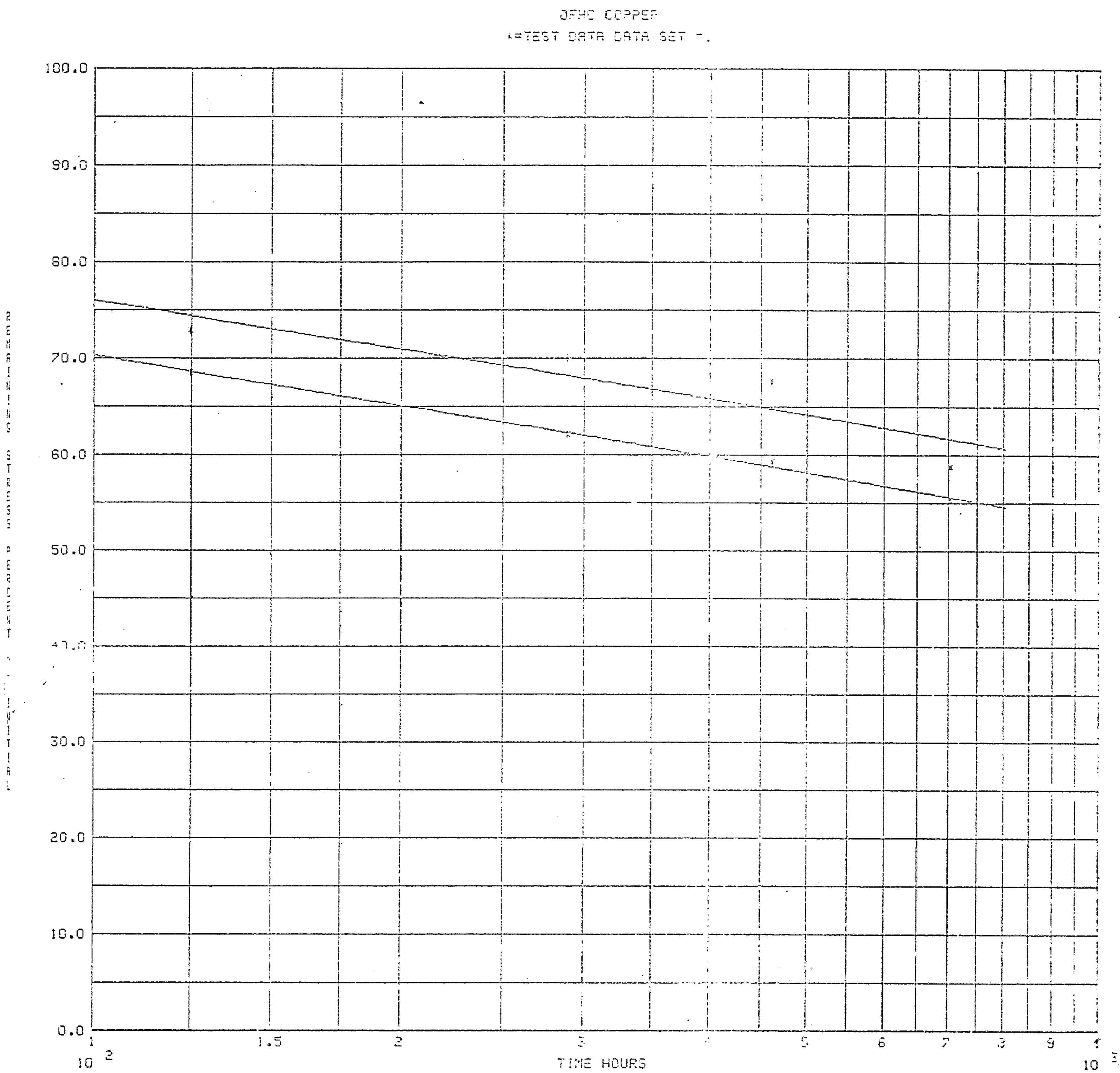
*=TEST DATA DATA SET =1
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.0
100.0
200.0
300.0
400.0
600.0
700.0
800.0
TIME HOURS
REMAINING STRESS PERCENT OF INITIAL

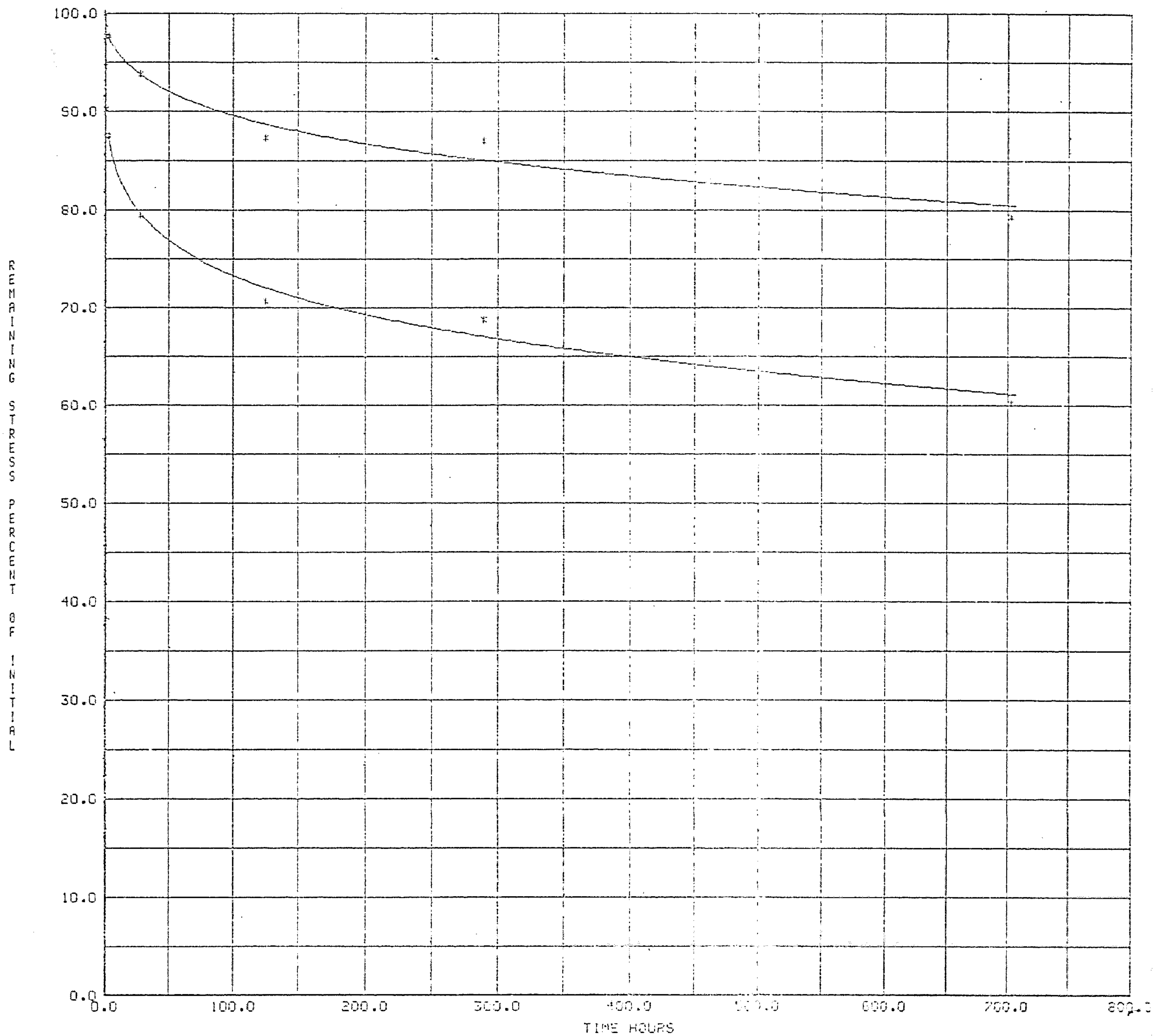
(107)


OFHC COPPER
*=TEST DATA DATA SET *.
REMAINING STRESS PERCENT OF INITIAL
TIME HOURS

(108)

ØFHC CU WITH 25 ØZ AG

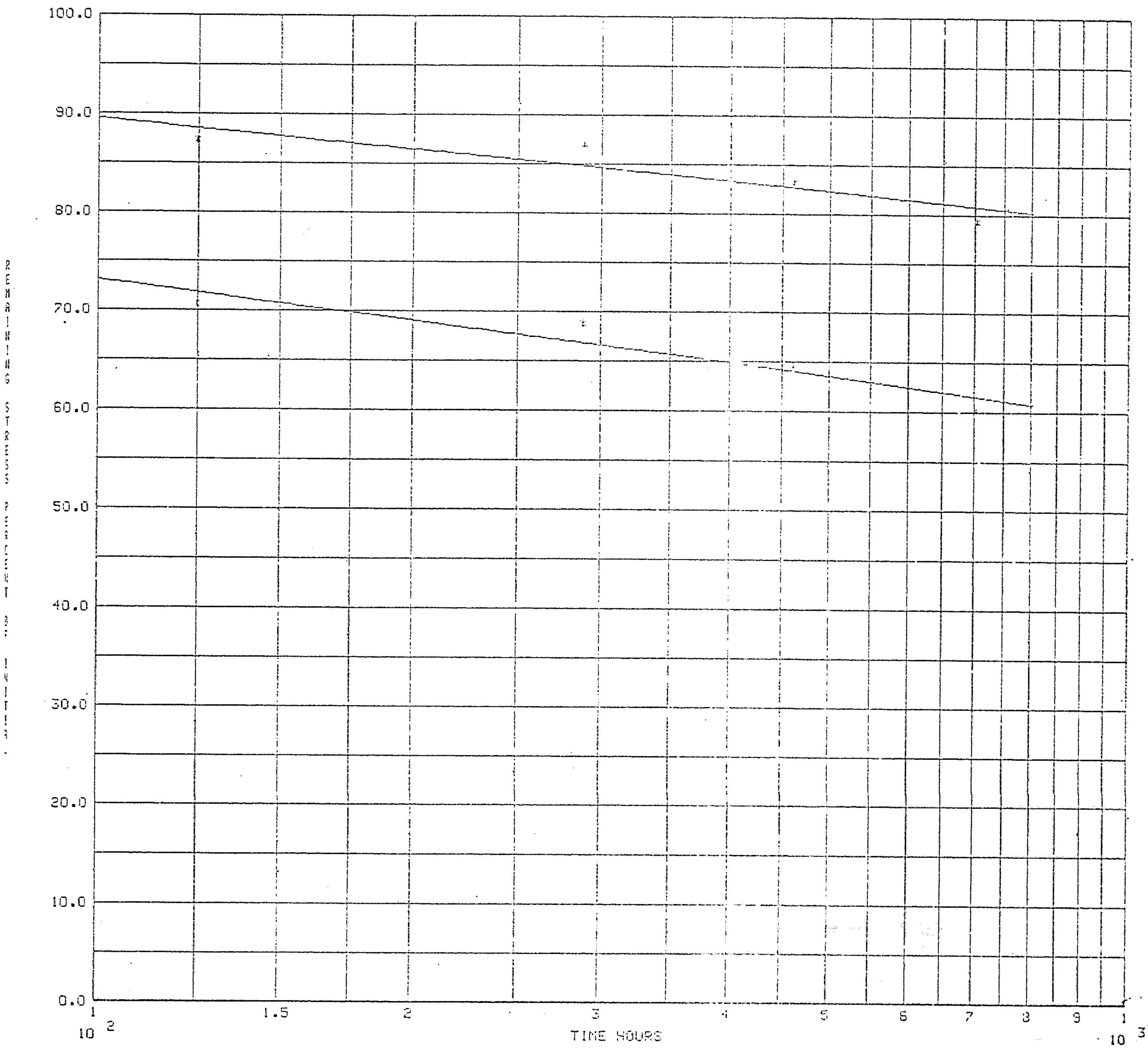
*=EXPERIMENTAL DATA CONTINUOUS CURVE =BEST FIT DATA SET =2 TEMP =200F



NUMB C0101 13.243 03/29
80XM274.HAL
PAGE NO 04

(109)

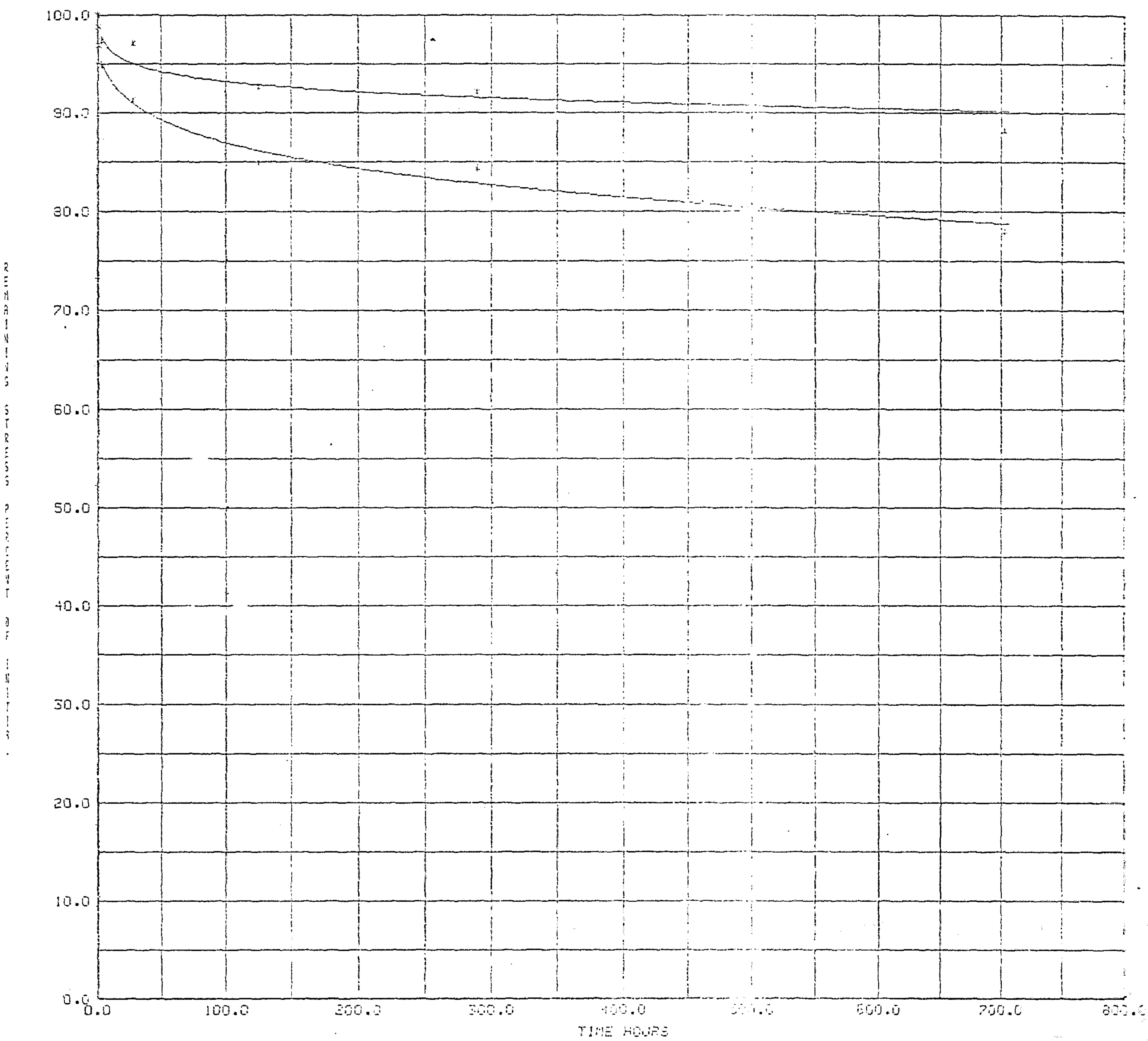
OFHC CU WITH 35 OZ AG PER TON
*=EXPERIMENTAL DATA CONTINUOUS CURVE =BEST FIT DATA SET =2 TEMP =200F



MB C0101 13.243 03/29
XM274,HAL
AGE NO 05

110

OFHC CU WITH 40 OE AC FIN TPI
*=EXPERIMENTAL DATA CONTINUOUS CURVE =BEST FIT DATA SET =3 TEMP =200F

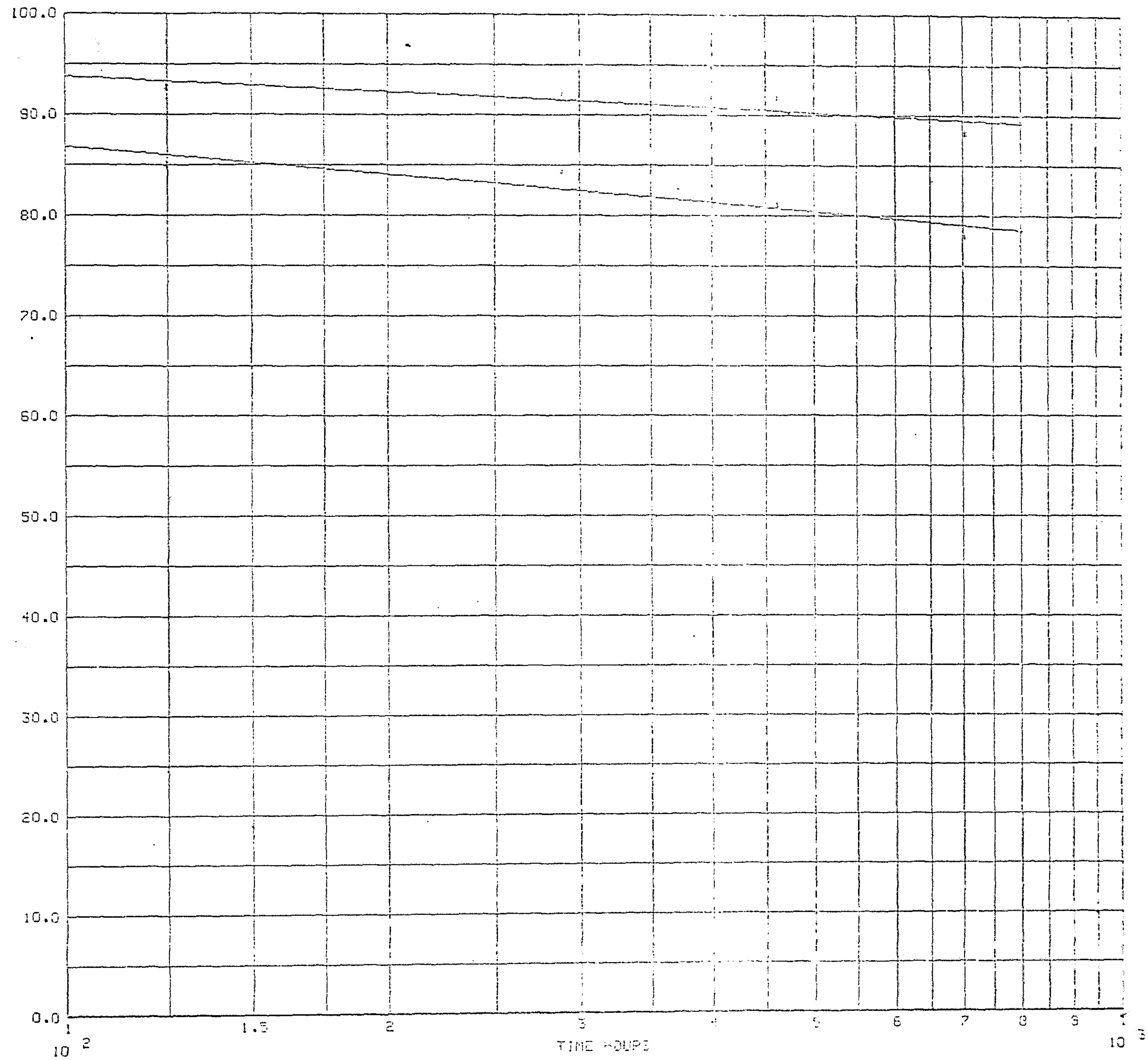


IB C0101 13.243 03/29
(M274.HAL
GE NO 06

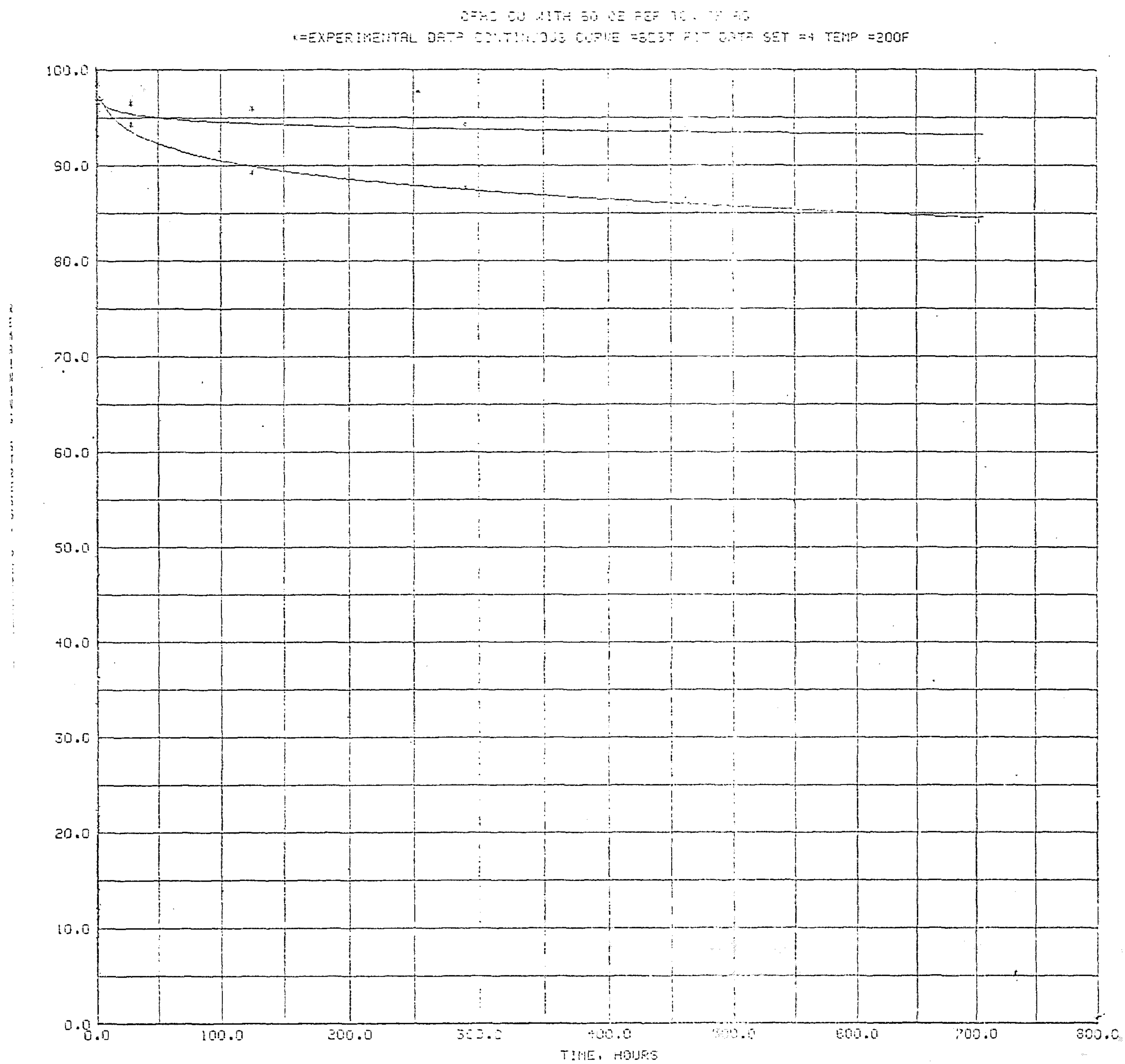
(111)

OFHC CU WITH 40 OB ...

*=EXPERIMENTAL DATA CONTINUOUS CURVE =BEST FIT DATA SET =3 TEMP =200F



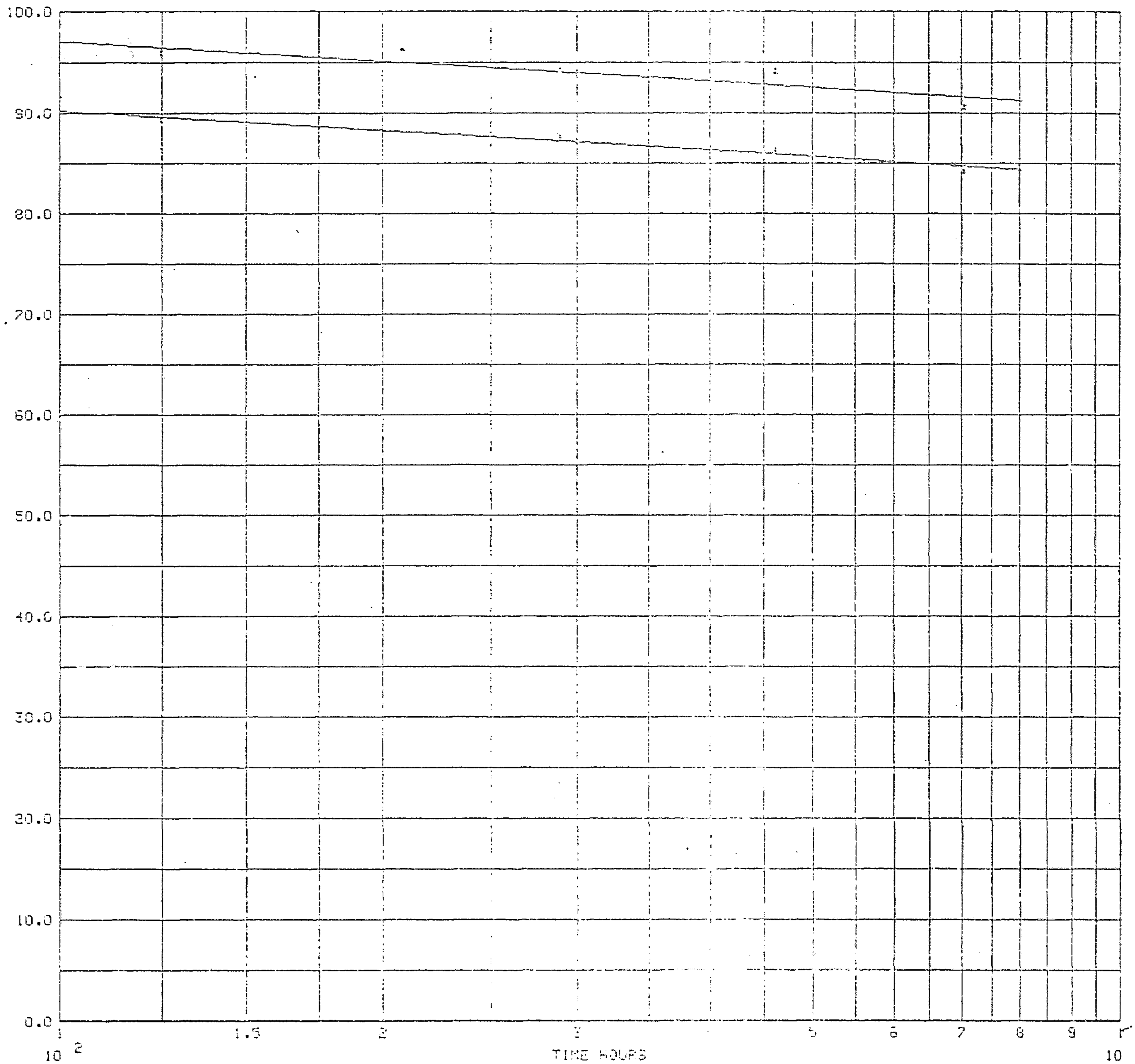
(112)


*=EXPERIMENTAL DATA CONTINUOUS CURVE =BEST FIT DATA SET =4 TEMP =200F
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0
TIME, HOURS

B C0101 13.243 03/29
XM274.HAL
GE NO 08

113

BFAC CU WITH 50 OE PER TON OF FG
*=EXPERIMENTAL DATA CONTINUOUS CURVE =BEST FIT DATA SET =4 TEMP =200F



SNUMB = C0206, ACTIVITY # = 01, REPORT CODE = 06, RECORD COUNT = 00171

ONLY STARE OUTPUT CALLED FOR

(124)

D A T A S E T N U M B E R 1

NOTEBOOK NUMBER 52731 PAGE 27
MATERIAL:HIGH PURITY COPPER AT 200 F
STRESS RELAXATION TEST
TEMPERATURE (DEGREES F):200.0
SPECIMEN DIAMETER (INCHES): 0.0201
NO. OF SPECIMEN AT EACH STRESS LEVEL: 2
FREQUENCY SQUARED = 421.28*STRESS

WHEN DATA IS PLOTTED LINEARLY, A CURVE IS FIT
ACCORDING TO THE EQN: Y=C1/(X**A2)+C2+C3*(X**A2)

WHEN DATA IS PLOTTED LOGARITHMICALLY, A CURVE IS FIT
ACCORDING TO THE EQN: Y=C1+C2*ALOG10(X)

****

STRESS LEVEL NO. 1 NOMINAL STRESS = 19.70KPSI

TIME HRS.	LOG OF TIME	RATIO	STRESS REMAINING (KPSI)
0.	.....	100.0	19.70
1.2	0.1	88.5	17.42
4.0	0.6	83.6	16.46
27.5	1.4	74.2	14.61
100.2	2.0	65.5	12.90
263.0	2.4	56.2	11.07
455.0	2.7	51.3	10.10
678.0	2.8	47.9	9.43

CONSTANTS FOR EQN. FITTING DATA PLOTTED LINEARLY:
A2= 0.06 C1= -156.14 C2= 444.63 C3= -199.86

DATA FOR EQN. FITTING DATA PLOTTED LOGARITHMICALLY:
C1= 107.92 C2= -21.28

AT T=40 YEARS, RATIO IS NEGATIVE.

STRESS LEVEL NO. 2 NOMINAL STRESS = 10.00KPSI

115

TIME HRS.	LOG OF TIME	RATIO	STRESS REMAINING (KPSI)
0.	.....	100.0	10.00
1.2	0.1	93.8	9.38
4.0	0.6	91.0	9.10
27.5	1.4	84.6	8.46
100.2	2.0	81.1	8.11
263.0	2.4	69.9	6.99
455.0	2.7	65.9	6.59
678.0	2.8	60.9	6.09

CONSTANTS FOR EQN. FITTING DATA PLOTTED LINEARLY:
A2= 0.03 C1= -777.10 C2= 1620.82 C3= -751.04

DATA FOR EQN. FITTING DATA PLOTTED LOGARITHMICALLY:
C1= 128.25 C2= -23.73

AT T=40 YEARS, RATIO IS NEGATIVE.

D A T A S E T N U M B E R 2

NOTEBOOK NUMBER 52731 PAGE 27
MATERIAL:HIGH PURITY CU WITH 25 OZ PER TON AG
STRESS RELAXATION TEST
TEMPERATURE (DEGREES F):200.0
SPECIMEN DIAMETER (INCHES): 0.0201
NO. OF SPECIMEN AT EACH STRESS LEVEL: 2
FREQUENCY SQUARED = 421.35*STRESS

WHEN DATA IS PLOTTED LINEARLY, A CURVE IS FIT
ACCORDING TO THE EQN: Y=C1/(X**A2)+C2+C3*(X**A2)

WHEN DATA IS PLOTTED LOGARITHMICALLY, A CURVE IS FIT
ACCORDING TO THE EQN: Y=C1+C2*ALOG10(X)

****

STRESS LEVEL NO. 1 NOMINAL STRESS = 21.60KPSI

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TIME HRS.	LOG OF TIME	RATIO	STRESS REMAINING (KPSI)
0.	.....	100.0	21.60
1.2	0.1	91.3	19.73
4.0	0.6	86.9	18.76
27.5	1.4	79.6	17.19
100.2	2.0	74.9	16.19
263.0	2.4	66.4	14.35
455.2	2.7	63.5	13.71
678.0	2.8	60.2	13.01

CONSTANTS FOR EQN. FITTING DATA PLOTTED LINEARLY:
A2= 0.04 C1= -203.44 C2= 538.89 C3= -244.39

DATA FOR EQN. FITTING DATA PLOTTED LOGARITHMICALLY:
C1= 109.55 C2= -17.47

AT T=40 YEARS, RATIO = 12.7 AND STRESS REMAINING = 2.74

STRESS LEVEL NO. 2 NOMINAL STRESS = 10.00KPSI

TIME HRS.	LOG OF TIME	RATIO	STRESS REMAINING (KPSI)
0.	.....	100.0	10.00
1.2	0.1	91.1	9.11
4.0	0.6	86.0	8.60
27.5	1.4	86.1	8.61
100.2	2.0	83.1	8.31
263.0	2.4	80.0	8.00
455.2	2.7	75.4	7.54
678.0	2.8	70.6	7.06

CONSTANTS FOR EQN. FITTING DATA PLOTTED LINEARLY:
A2= 0.02 C1=-2213.68 C2= 4441.06 C3=-2138.72

DATA FOR EQN. FITTING DATA PLOTTED LOGARITHMICALLY:
C1= 113.24 C2= -14.52

AT T=40 YEARS, RATIO = 32.7 AND STRESS REMAINING = 3.27

MB C0206 17.538 03/29
XM274.HAL
GE NO 01

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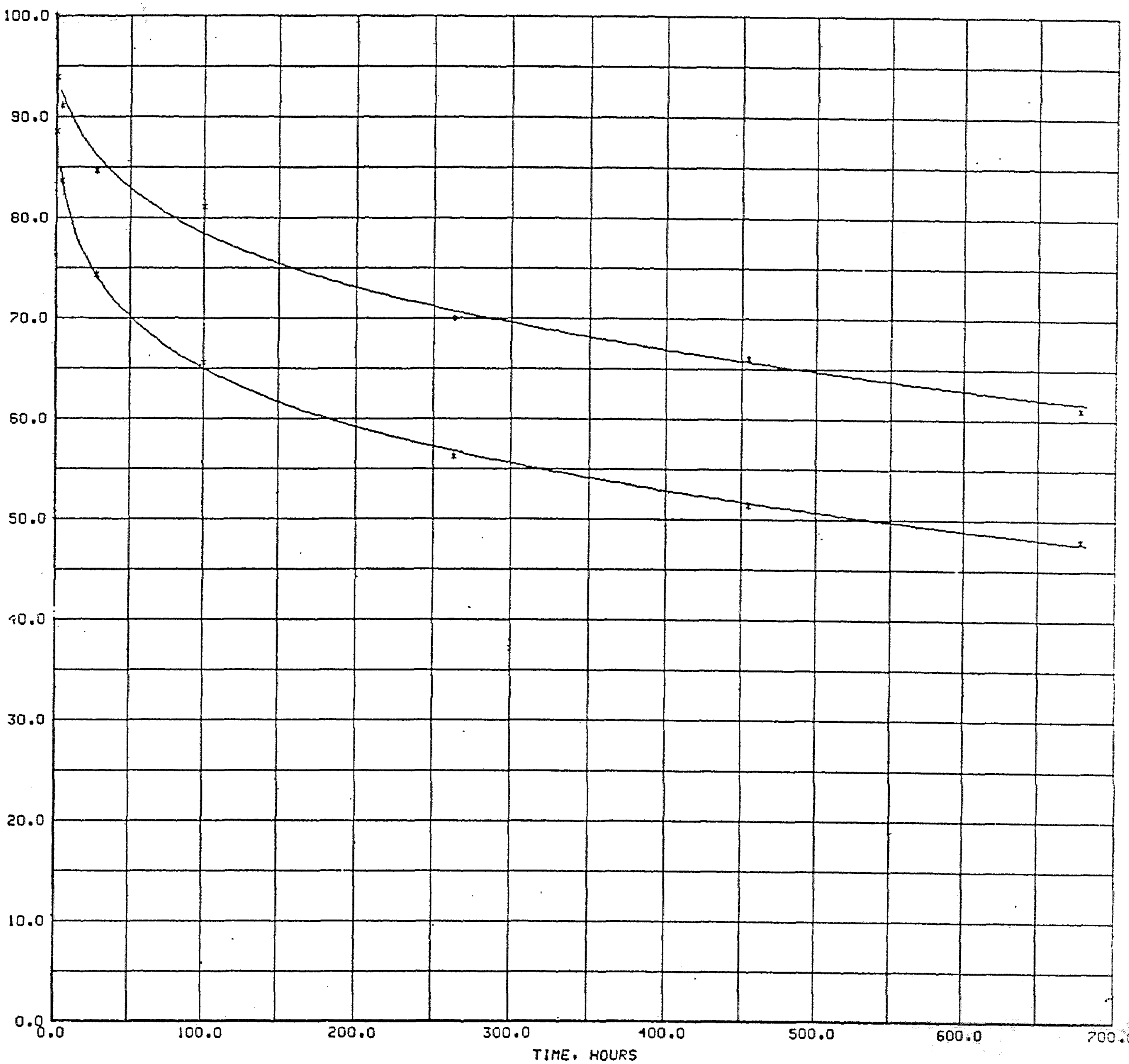
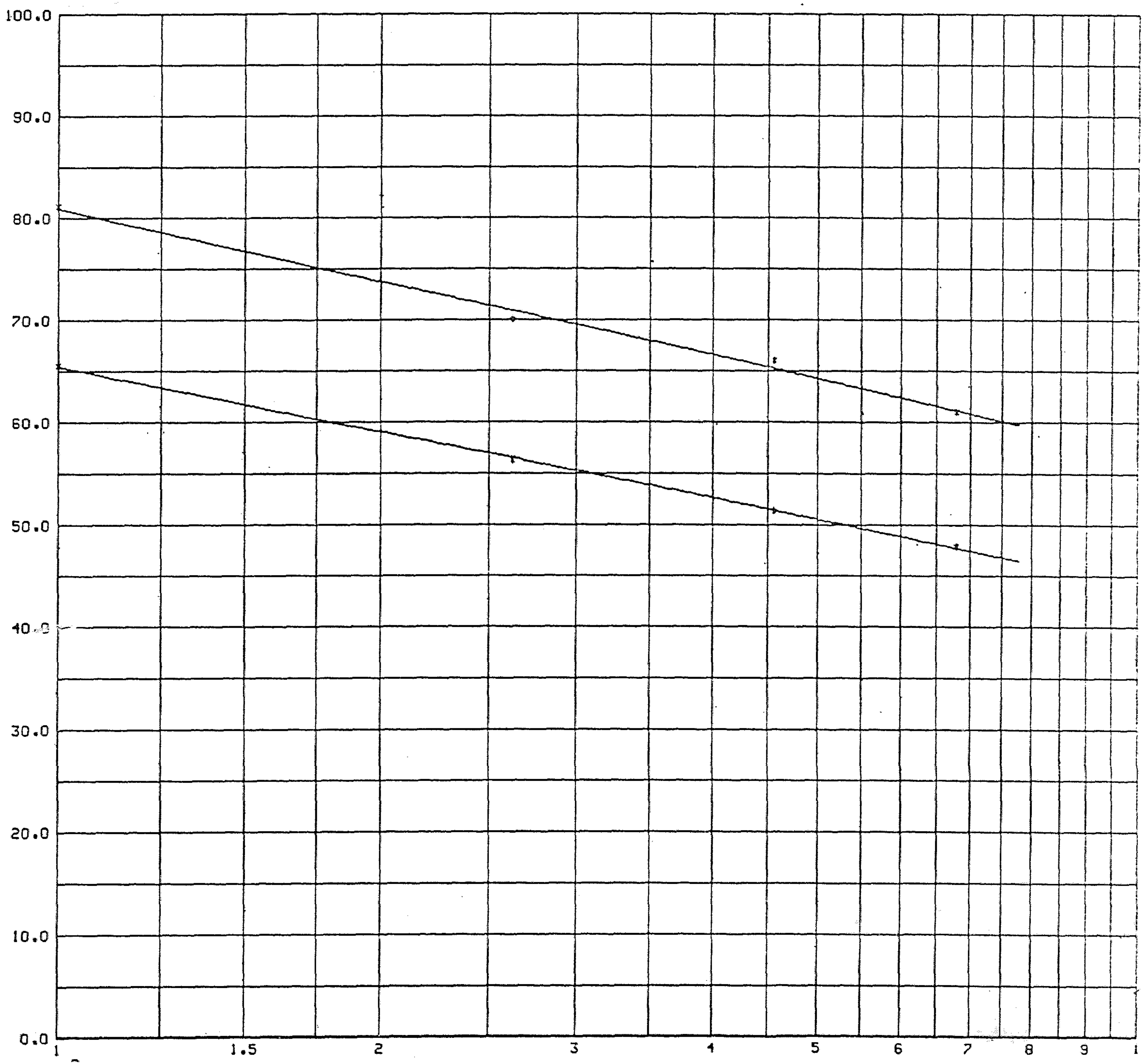
HIGH PURITY COPPER WIRE AT 200 F
*=TEST DATA CONTINUOUS CURVE =BEST FIT DATA SET =1



MB C0206 17.538 03/29
XM274.HAL
GE NO 02

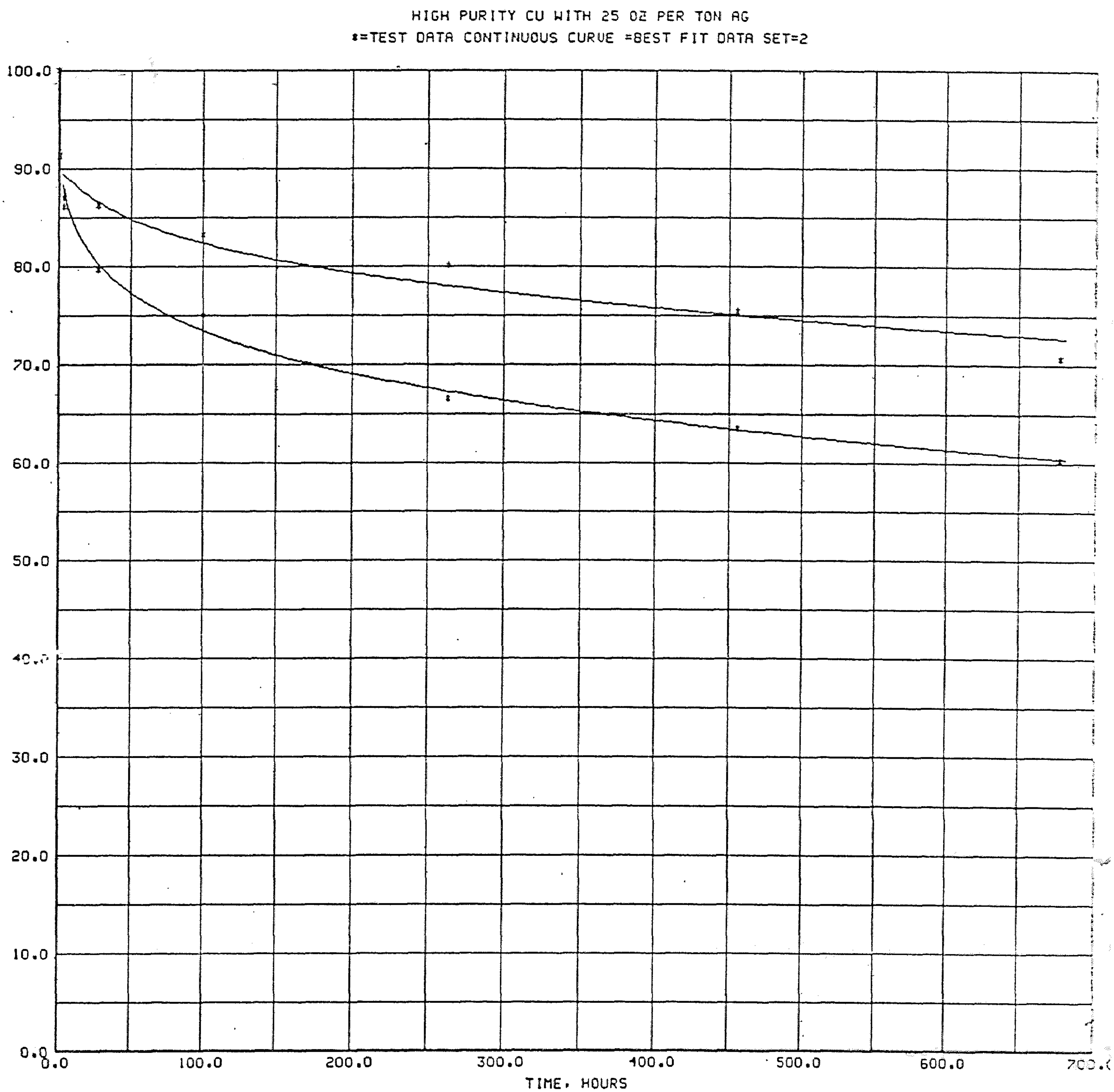
(118)

HIGH PURITY COPPER WIRE AT 200 F
*=TEST DATA CONTINUOUS CURVE =BEST FIT DATA SET =1



MB C0206 17.538 03/29
XM274.HAL
GE NO 03

119

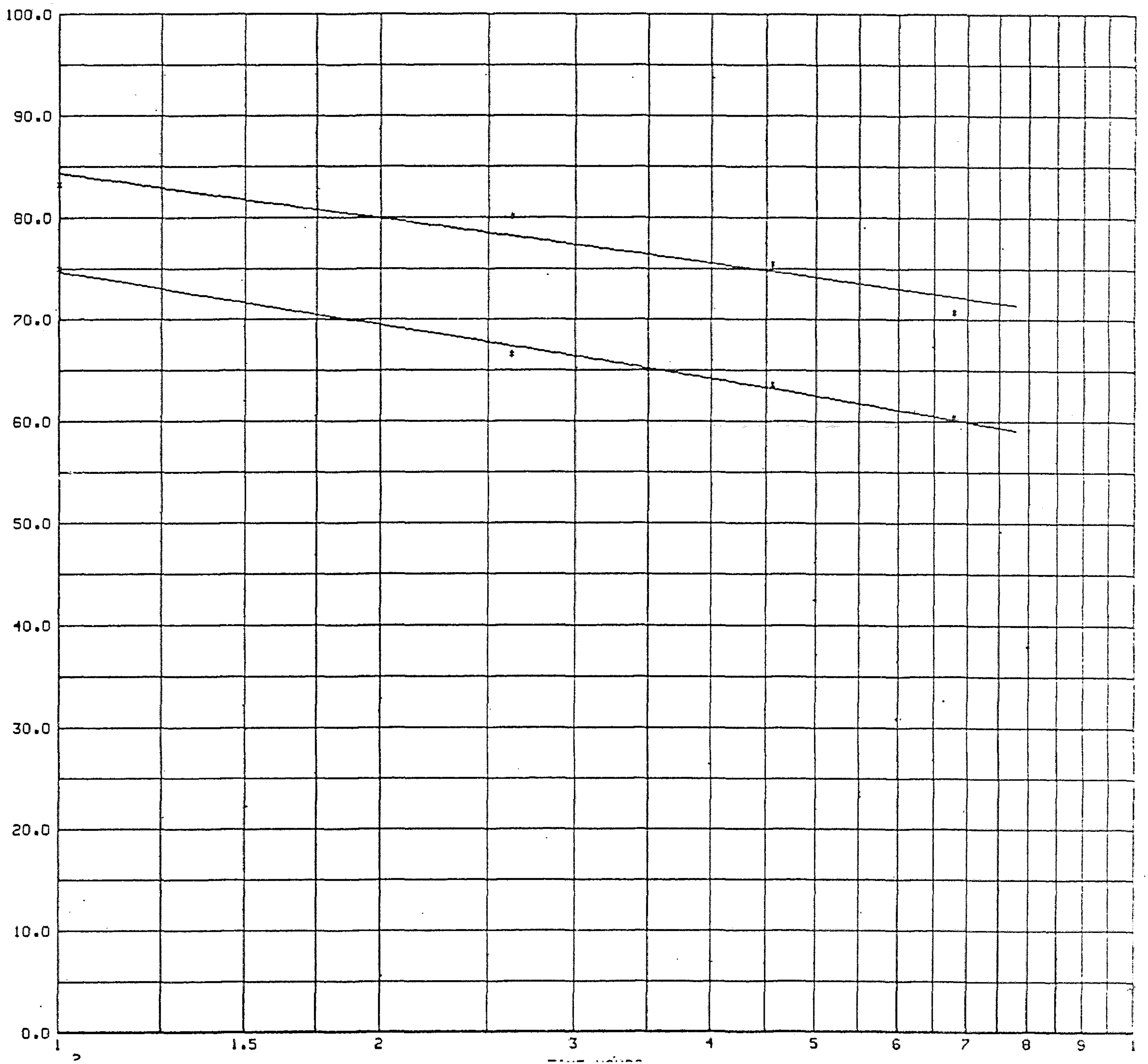


B C0206 17.538 03/29
M274.HAL
E NO 04

(120)

HIGH PURITY CU WITH 25 OZ PER TON AG

*=TEST DATA CONTINUOUS CURVE =BEST FIT DATA SET=2



APPENDIX II - EXAMPLE OF EXPERIMENTAL DETERMINATION OF CONSTANTS IN BAILEY NORTON EQUATION

Consider the creep strains printed out for OF copper at 250 Deg F (page 30 of the computer printout). The creep strains for the two stress levels used and for the various time intervals are entered in Table A-1.

Table A-1

Time, hr.	1.3*	4.0	29.0	49.0	120.8	222.3	337.9	385.5	480.7	625.1	1200.7
Stress, ksi				Creep Strain, $\varepsilon^{(c)} x10^3$							
10.0*	1.92*	2.40	4.48	5.36	7.21	8.74	9.95	10.36	11.09	12.02	14.78
20.6	4.42	7.03	14.44	17.36	25.26	34.41	42.9	46.1	52.2	60.7	90.3

The smallest creep strain, stress and time are marked with an asterisk. They are denoted by $\varepsilon^{*(c)}$, $\sigma^{*(c)}$ and t* respectively.

A new Table A-2 is now prepared entering $\log \varepsilon^{(c)}/\varepsilon^{*(c)}$, $\log \sigma/\sigma^*$ and $\log t/t^*$.

From Table A-1

$$\varepsilon^{*(c)} = 1.92 \times 10^{-3}$$

$$\sigma^* = 10.0 \text{ ksi}$$

$$t^* = 1.3 \text{ hr}$$

According to the Norton-Bailey Creep Law, the creep strain developed during a constant stress creep test may be expressed as:

$$\varepsilon^{(c)} = \left(\frac{1+\mu}{\tau}\right)^{1/(1+\mu)} \left(\frac{\sigma}{\sigma_m}\right)^{m/(1+\mu)} t^{1/(1+\mu)}$$

and since ε^*, σ^*, t^* define a point on the creep curve:

$$\varepsilon^{*(c)} = \left(\frac{1+\mu}{\tau}\right)^{1/1+\mu} \left(\frac{\sigma^*}{\sigma_m}\right)^{m/(1+\mu)} t^{1/1+\mu}$$

It follows that:

$$\log \frac{\varepsilon^{(c)}}{\varepsilon^{*(c)}} = \frac{m}{1+\mu} \log \frac{\sigma}{\sigma^*} + \frac{1}{1+\mu} \log \frac{t}{t^*}$$

Table A-2 Log $\varepsilon^{(c)}/\varepsilon^{*c}$

log t/t*	0.00	0.488	1.348	1.576	1.968	2.233	2.415	2.473	2.567	2.682	2.966
0.0	0.0	0.093	0.367	0.446	0.574	0.652	0.714	0.732	0.761	0.797	0.886
log σ/σ* 0.302	0.362	0.564	0.876	0.956	1.119	1.253	1.349	1.380	1.434	1.500	1.672

A plot of $\log \frac{\varepsilon^{(c)}}{\varepsilon^{*(c)}}$ vs $\log t/t^*$ for various $\log \sigma/\sigma^*$ is shown on the auxiliary diagram. The slope of this plot is given by $\frac{1}{1+\mu}$ and the y-intercept by $\frac{m}{1+\mu} \log \frac{\sigma}{\sigma^*}$. From these determinations the constants may be evaluated.

For $\log \sigma/\sigma^* = 0$

$$\log t/t^* = 3.0$$

$$\log \frac{\varepsilon^{(c)}}{\varepsilon^{*(c)}} = 0.88$$

$$0.8 = \frac{3.0}{1+\mu} \therefore 1 + \mu = 3.4$$

$$\mu = 2.4$$

For $\log t/t^* = 0.0$:

$$\log \sigma/\sigma^* = 0.3$$

$$\log \varepsilon^{(c)}/\varepsilon^{*(c)} = 0.35$$

$$0.35 = \left(\frac{m}{3.4}\right)(0.3) \therefore \quad m = 4.1$$

$$\sigma_m = \sigma^*\left[\frac{t^*(1-\mu)}{\tau}\right] [\varepsilon^{*(c)}]^{-\frac{(1+\mu)}{m}}$$

$$\sigma_m = 10.0\left[\frac{(3.4)(1.3)}{\tau}\right] (1.92\text{x}10^{-3})^{-\frac{(3.4)}{4.1}}$$

One may choose τ and solve for σ_m

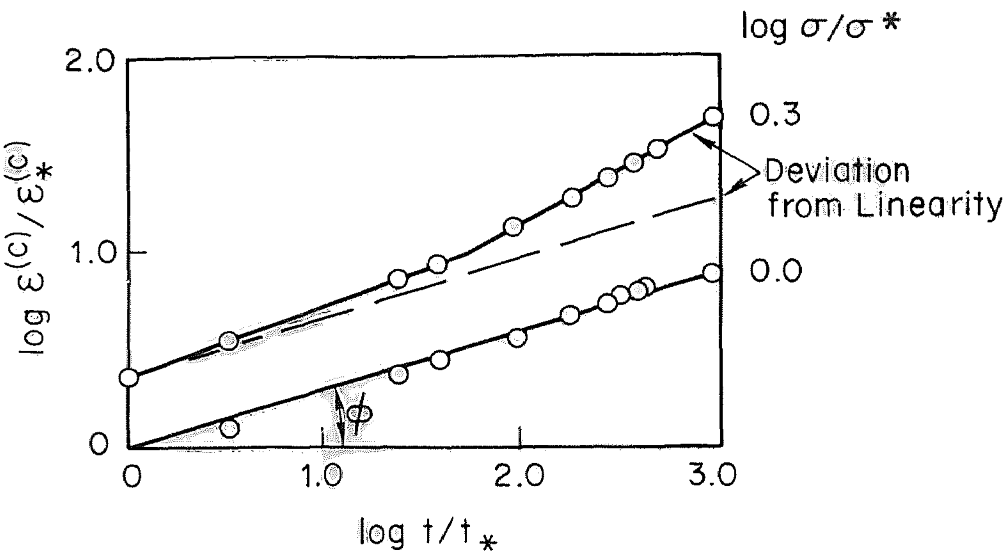


FIG. A2.1 AUXILIARY DIAGRAM FOR OBTAINING CONSTANTS IN NORTON-BAILEY CREEP LAW FOR OF COPPER AT 250 DEG F.